Is it Regal or Non-Regal? Unraveling Regal Looking Off-Metal Two Reales Utilizing a SEM/EDS Triple Tier Analytical Approach

Introduction: During a review of my Contemporary Circulating Counterfeit (CCC) Two-Reale Collection more commonly known as Kleeberg CCC Two Reales (1) with other specialists on the Facebook channel "Contemporary Circulating Counterfeit Coins – The Good Ones" several examples in "probable" off-metal alloys were reported and suggested as regals contrary with my initial XRF surface analysis. This was observed going through each Counterfeit Two Real example in my collection for a proposed future book on these so-called Kleeberg's. For this research paper only, the author is using the word "probable" for the preliminary XRF semi-quantitative analysis which was performed by this author utilizing either his own SEM/EDS surface analysis, benchtop XRF devices with a sealed vacuum analysis chamber (i.e., EDAX Orbis XRF Analyzer) or the XRF was done in the open atmosphere. Different pieces of equipment were utilized over several decades depending on available equipment during my years working at different companies having these Material Analysis devices in the company's laboratories when working as a Safety/Environmental Manager. The word semi-quantitative is utilized here when we examine coins at the surface or at the so-called corrosion layer. It's known that the alloy on the surface will differ with the core and just beneath the corrosion layer. However, the overall generic alloy description such as high copper, brass (Cu/Zn) or bronze (Cu/Sn) as examples will normally not change but normally only with the quantitative levels of the individual metals due to metal movement internally and a coin's surface reaction with commonly found surface contaminants such as sulfur, iron, arsenic, silicon and/or chlorine. During the book write-up of Contemporary Portrait Eight Reales – The Un-Real Reales (GNL Book) by Robert Gurney (2) this co-author of the GNL team had come across various regal looking pieces either cast or struck made in casting molds or via different die transfer processes. Some examples include GNL#1791-O: F/R: MoFM-006 on page 292 considered a copper or brass alloy and crudely cast from a mold that was copied from a genuine coin. Some letters being reengraved and considered a pre-1830 cast type. Another example of the same year GNL# 1791-O: I/R: Mo FM-009 was considered a debased silver alloy composition with dies of a regal style and possibly an early die transfer method. Another manufacturing method was also considered that a set of matrix punches was created from the original coin creating these regal looking off-metal counterfeits. Within GNL other regal looking pieces were reported: page 295 (GNL#1791-O:L/R: Pts IJ-001), page 304 (GNL# 1792-O:J/R:MoFM-007), page 317 (GNL#1794-O:L/R:MoFM-009), page 319 (GNL# 1794-O:R/R:NG M-001), 327 (GNL#1795-O:K/R:MoFM-007), page 337 (GNL#1797-O:E/R:MoFM-010), page 340 (GNL#1797-O:L/R:MoFM-008), page 346 (GNL#1799-O:C/R: Pts PP-001), page 367 (GNL#1803-OB/R:PtsPJ-001), page 368 (GNL#1803-O:E/R:MoTH-002),page 399 (GNL#1808-O:P/R:MoTH-008) and page 473 (GNL#1820-O:D/R:MoJJ-002). One of these examples GNL#1803-O: B/R: Pts PJ-001 a brass/bronze alloy being either a cast or early transfer die process piece being regal in design but the dentil arc on reverse ends before the edge of the coin demonstrating its CCC character. XRF analysis confirmed Cu (82.27%), Zn (10.96%), Sn (6.0%) and Pb (0.4%). The major point here is that these regal looking CCC pieces in the Eight-Reale denomination are being repeated here with these Kleeberg CCCs for the two-reales denomination.

In the preparation of the GNL book not all pieces were XRF analyzed, and the type of Die Transfer process used was speculated based primarily on Robert Gurney's experience of over

50 years studying this counterfeit family and observing the coin's different manufacturing signatures. This was not wrong, but no back-up Material Analysis was performed on their metal assay or SEM/EDS analysis was performed to confirm if the GNL regal looking varieties mentioned previously were confirmed as die struck or cast other than an opinion from their stylistic & physical metrological characteristics as is normally done with other contemporary circulating counterfeit series.

You can produce transfer dies by electroplating and casting, but the first step is always the same you need to get an imprint of an authentic or fake coin from which you want to produce the dies. In Charles M. Larson's book titled Numismatic Forgery (3), he explains one form of die transfer process as Explosive Impact Copying which he defines as "The creating of dies for forgery by driving the image of a genuine coin into a steel blank with an explosive force, causing the steel to take the image of the coin so quickly that the softer coin literally does not have time to spread out or flatten. Some of the best forgeries known to have been produced using this method and the best of them are virtually undetectable. Casting is the creation of an object by introducing molten metal into a mold. One further method is the Lost Wax Process which is a method of creating molds for casting by investing plaster around a wax model of the object to be cast. When the plaster sets, the mold is turned upside down and heated causing the wax to melt and burn out, thus becoming "lost." The resulting mold will contain detail of a very high quality. The point here is that there are various methods to create a regal looking die, but can SEM/EDS analysis help determine if the coin produced can be linked to a specific die transfer process at this time? At this time the answer is "NO" but what can be done is to look at the composition of these die transfer process or cast produced regal looking CCCs at the surface, beneath the surface or more specifically beneath the corrosion layer by polishing an area of the coin and to determine their metal compositions more accurately than at the surface and if they are cast or die struck. This is what was left out due to time and money restrictions with these CCC8R GNL varieties that were stylistic & physically described as either casts or die struck transfer pieces. How this will be performed will be described in the next section called Sample Methodology utilizing SEM/EDS analysis at an independent testing laboratory at Michigan State University – Material Analysis Laboratory (MSU). As an example, some collectors believe that if a CCC has a central die depression area or what is commonly called central die failure is it from a buckling die event, caused by overused dies or possibly can it be also from a die transfer process? At this time the technology is not there in my opinion to differentiate a coin's surface features to a specific die transfer process however we can with nearly a 100% confidence level determine a coin's manufacture process if it was produced either by casting or struck by dies (i.e., die struck) using SEM Micrograph Microstructure analysis. This will be explained in the Analytical Methodology section but prior to this the Sampling Methodology will be discussed.

Sampling Methodology/Strategy

As explained previously during the overview of my Kleeberg CCC2R collection on the Facebook CCC – The Good Ones site ~ (10) coins were proposed as regal pieces based on their motifs and letter punches being identical to 90% silver regal (i.e., legitimate) pieces.

These were later classified by this author as Specimens (A-J) and will be discussed individually below. It's been determined at this time that even though they were found to be off-metal alloys via surface semi-quantitative XRF analysis and additionally being non-90% silver by a Sigma

Analyzer apparatus (4) they will not be considered as Kleeberg varieties in the upcoming book by lead author, counterfeit researcher and collector Winston Zack. The reason being the book will be addressing only hand cut pieces as Kleeberg CCC2R's. These regal looking pieces do still "qualify" as Kleeberg's as they were made in the 19th century and are of the same manufacturing "fabric" as the previously mentioned Class 1 GNL pieces. In GNL under the Definitions section a Class 1 – Contemporary Circulating Counterfeit (CCC) is defined as: A debased coin produced with reduced or no silver content, that was made to pass as current money or billion in various countries without regard to date of production if the assay of silver is below 800 fine silver. This term may also be abbreviated as Class 1. This is different than Class 2 which is above 800 fine silver and was produced between 1830-1930. There is a slight difference within Kleeberg's however where debased silver issues are not allowed in this CCC Family and the allowed Kleeberg alloys are non-precious metal base alloys such as copper, brass, German silver, bronze or brass/bronze mixtures. Due to the confusion with collectors in allowing regal looking pieces within the Kleeberg CCC Family with off-metal or non-silver alloys and the current lack of Material Analysis equipment currently available to collectors to determine their metal alloys accurately in this counterfeiting family it was decided to exclude these regals looking off-metal pieces. Nevertheless, due to their historical importance the author feels possibly a separate chapter is worthy for these pieces in the upcoming Kleeberg book. The author will analyze two pieces via SEM/EDS through an independent testing laboratory but will list all pieces with their diagnostic XRF surface semi-quantitative analyses and discuss why he has selected only Specimens B & C from this Specimen A-J group. These specimens during their acquisitions were given Kleeberg #'s by the author so these numbers will be retained for this paper. It's also been decided that for the upcoming Kleeberg book a new classification system may be needed. Listed below is the Kleeberg Specimen (A-J) listing:

1. Specimen A. K.76B-M33. Silvered Brass Alloy. Central Die Failure and probably of a die transfer process. Weight – 6.77 grams. See the Facebook #9 specimen. **NOT SELECTED**.
2. Specimen B. K.19A-L37. Silvered surface copper alloy or debased silver. Crude single file marks on edge. Pb = 4.47% in XRF assay. Weight – 5.9 grams. See the Facebook #99 specimen. **SELECTED**.
3. Specimen C. K.19A-L37. Mercuric amalgam silvering over a copper alloy. Possibly a cast bronze alloy with Pb=6.8%. A good microstructure SEM analysis candidate and the same variety as Specimen B so from the same manufacturing operation. See Facebook #100. **SELECTED**.
4. Specimen D. K.89D-L54. A low zinc (10.3%)/Tin (4.7%) brass/bronze mixture alloy. Possibly a cast type with Pb=3.6%. Since Specimen C is a possible cast type this will be considered. Weight – 4.41 grams. See Facebook #38. **NOT SELECTED**.
5. Specimen E. K.00A-L36. Silvered brass (Cu/Zn) alloy. Like specimen B but with Pb trace at 0.1%. Weak central die failure and a probable die transfer piece possibly through some type of impact die transfer process. HIS & PAN with different alignments so not a perfect regal type. Weight – 4.80 grams. Facebook#62. **NOT SELECTED**.

6. Specimen F. K.80A-L34. Silver solder on a base alloy of Cu/Zn/Ni/Pb. The silver soldering on the obverse only. Weight – 6.04 grams. Facebook #13. **NOT SELECTED**.

7. Specimen G. K.00A-M43. High Cu (58.5%) with Zn & Ni and Pb=5.01%. An XRF re-evaluation needed with a benchtop as XRF gun seems off based on these metal percentages. Weight = 4.94 grams**. NOT SELECTED**.
8. Specimen H. K.82D-M40. Silver wash over a copper base alloy with high Pb=6.74%. Weight = 5.75 grams. A silvered example somewhat like Specimen B so **NOT SELECTED**.
9. Specimen I. K.00B-G6. German silver type alloy? Currently an XRF gun analysis suggesting German silver but needs to be reverified. Pb=1.14 % with blob lettering. If a second round of sampling is performed an excellent candidate reverification. **NOT SELECTED**.
10. Specimen J. K.82F-M47. Sheffield Plate over an iron-based alloy. Previous SEM/EDS analysis. A specimen needing to be reverified. Weight – 6.7 grams. **NOT SELECTED**.

Due to the high cost of analysis with SEM/EDS at just over $100/hour and my discussions with the MSU Material Analysis Laboratory (MSU) it was decided to analyze just two examples. As we can see from Specimens A-J above we see the major metal alloy types normally seen in the Kleeberg CCC Family with the accepted and popular crude hand cut types: A silvered base alloy, a non-silvered example of a base alloy such as copper, brass, bronze, brass/bronze mixture and German silver. In this case we do also have an odd ball in Specimen J which is a Sheffield type or silver-plating over a base metal composition of copper/iron which is occasionally seen in the GNL CCC8R CCC Family. Specimens B&C were selected since both are of the same manufacturing operation since “both” pieces are of the same Kleeberg variety number, and one is a silvered surface or debased silver alloy and the other a possible silvered bronze/leaded cast type so these two were considered a perfect duo to measure the effectiveness of the three-tier SEM/EDS analysis. Specimens will be analyzed both in an unpolished & polished state.

Analytical Methodology

SEM (Scanning Electron Microscope) equipped with EDS (Energy Dispersive X-ray Spectrometer) can capture detailed images and identify elements simultaneously on the surface of samples. For imaging, SEM is widely used since it needs minimal sample preparation and produces excellent resolution, unique contrast, and a large depth of field. When paired with an EDS system, elemental information of the imaged area can also be derived. SEM/EDS is ideal for imaging and elemental analysis applications requiring higher resolution than optical microscopy and identifying elemental make up.

In SEM, an image is formed by scanning a focused electron beam, usually with energies of 1 to 20 keV, across a sample and detecting the ejected secondary or backscattered electrons. The incident electron beam, when imparting energy to the sample, can cause emission of x-rays that are characteristic of the sample atoms. The energies of the x-rays are characterized (5).

The typical spatial resolution of SEM imaging is about 5-10 nanometers. SEM-based EDS is primarily a qualitative technique providing data from about a micrometer in diameter and a micrometer deep.

The strengths of SEM/EDS lie in its ability to provide rapid, high-resolution imaging, and enabling quick identification of elements present. Its excellent depth of field and versatility as a platform supporting various tools make it an asset.

For these two specimens both with the same die variety and both being severely underweight to their KM # listed regal weight at 6.7668 grams the author found with preliminary semi-quantitative XRF analysis we have a delicate extremely thin mercuric silvered surface in Specimen C and Specimen B was classified as a very low zinc brass alloy with crude single file marks on the edge and possible being surface silvered. Specifically:

- Both coins will be analyzed initially without the surfaces being polished (i.e., generally the rim area to avoid damage to the obverse & reverse as these are collectible artifacts). For normal metal assays this is fine to get a "generic" idea of the alloy as performed previously by this author using XRF analysis. This is part of the **Phase I** results which will just confirm the author's previous XRF results.

- Since for cast and struck differentiation with SEM Microscopy Micrograph interpretations its recommended to polish the surface area to reveal the area beneath the corrosion area which usually equates to removing 200-600 micrometers (um) of the top surface of both coins as per discussions with MSU. This will be done Phase II. This will allow an easier determination of the coin make-up whether dendritic (cast) or twin line (die struck). Scanning electron microscopy works by scanning a sample with electron beams. An electron gun fires these beams, which then accelerates down the column of the scanning electron microscope. During this action, the electron beams pass through a series of lenses and apertures, which act to focus it. This occurs under vacuum conditions which prevents molecules or atoms already present in the microscope column from interacting with the electron beam. This ensures a high quality of imaging. The vacuum also protects the electron source from vibrations and noise. The electron beams scan the sample in a raster pattern, scanning the surface area in lines from side to side, top to bottom. The electrons interact with atoms on the surface of the sample. This interaction creates signals in the form of secondary electrons, backscattered electrons and rays that are characteristic of the sample. Detectors in the microscope pick up these signals and create high-resolution images displayed on a computer screen (5).

- In a random polished area in **Phase II** a single target metal assay (i.e., Map Sum Spectrum) as previously done on the surface corrosion layer (Phase I sampling) will be performed. If surface silvered generally any degree of polishing will destroy the thin delicate silvering layer applied by the counterfeiter. So, this is the reason two phases of sampling were required to understand the make-up of the host coin being surface silvered or possibly silver debased with copper. Both possibilities exist when no Hg is detected at the surface.

- It's advisable to determine if a coin is cast or struck by removing the corrosion layer to properly read the SEM micrographs as dendritic cast or a twin-line struck microstructure.

With these two types of sampling (i.e., Phase I Unpolished & Phase II Polished Analysis) results we can then confirm if the sample is die struck or cast and more accurately determine its true metal alloy composition when examining a coin's polished area after surface contaminants are removed.

Figure 1: Coin #1. Specimen B of the Kleeberg Group (A-J) being of a silvered surface over a high copper alloy composition based on preliminary XRF analysis performed by this author prior to submitting the coin to MSU for SEM/EDS Analysis. Obverse – top photo. Reverse – bottom photo.

Figure 2: Coin #2. Specimen C. A Bronze Alloy with surface silvering from the initial XRF analysis performed by this author prior to its submittal to MSU SEM/EDS Analysis. Obverse – top photo. Reverse – bottom photo.

For the **Phase III analysis** “five” standards were submitted of George II and George III cast and struck issues. This was submitted to aid the analysts at MSU and this author when examining these known cast and struck copper issues to have a better understanding of what a dendritic cast and twin (grain) line SEM micrographs will appear under different SEM magnifications. It’s true that based on a counterfeit halfpence metal assay a counterfeit numismatic expert can differentiate between cast and struck by the surface features and metrological properties but sometimes buried struck and genuine cast examples can be difficult to differentiate due to the coin’s corrosive surface features resembling a cast produced coin in a mold. These cast/struck examples included these five examples, and their photos appear in the Phase III analysis section. The three cast specimens and two struck pieces are:

1. 1730 English George II Cast Halfpence.
2. 1739 English George II Cast Halfpence
3. 1743 English George II Cast Halfpence
4. 1775 English George III Struck Halfpence
5. 1782 Irish George III Struck Halfpence

Along with these cast and struck George II and George III coins a 90% silver two-reales coin of an 1802 Lima Peru 2-reales IJ Assayer with a weight close to regal at 6.7668 grams will be examined in the **Phase IV section** of this paper for comparison purposes to Coins B & C.

Figure 3-1 Obverse of the 1802 Lima Peru 90% Silver Regal IJ Assayer with a KM# 95 attribution.

Figure 3-2 Reverse of the 1802 Lima Peru 90% Silver Regal IJ Assayer with a KM# 95 attribution.

So, as an overview the sampling methodology will consist of the following:

- **Phase I**: Two coins labeled B & C from the initial A-J group of my Kleeberg CCC2R collection which have regal motifs but from my XRF analysis are off-metal alloys whose surfaces appear to be both silvered will be confirmed as well as their host alloys if 90% silver or are off-metal CCC's.
- **Phase II**: For Coins B & C we wish to determine their metal assays by SEM/EDS and review their microstructure micrographs via SEM. It was decided to do three target areas of the unpolished coin's surface of B & C so a well representative idea of their metal assay will be achieved. Only one target area of the polished surface area of the rim area will be performed since a high copper result will indirectly prove it's not a 90% regal silver coin since an ~90% silver alloy will reveal this level of Ag from surface to core.
- **Phase III**: It was decided by the author to compare the SEM micrograph microstructures of "confirmed" struck and cast George II & George III CCCs which will also add knowledge to this area of counterfeit collecting and we can then compare these SEM micrographs of cast and struck halfpence also being of a similar high copper assay to these two probable high copper assay two-reales K.19A-L57 test specimens B & C.
- **Phase IV**: Finally, for completeness it was decided to test a legitimate regal two reales 90% silver 1802 Lima, Peru specimen so the reader can review this data under a SEM/EDS full analysis. We will then compare these results to the George II/III CCCs but more importantly compare the results to the two off-metal copper regal looking two reales pieces B & C.

Analytical Results (Unpolished & Polished Results)

Phase I (Unpolished Coins B & C). Three Target Areas/Specimen Analyzed by SEM/EDS)

The results of this section will be for the examination of three random target areas chosen by MSU of unpolished areas of Coins B & C, the two Kleeberg regal looking off-metal (i.e., non-90% silver) pieces. Initially an EDS metal assay by weight percentages is calculated on what is called a Map Sum Spectrum. This is followed by a SEM Micrograph Microstructure of the same area under a chosen specific magnification level to determine if the coin's microstructure is cast dendritic or twin (grain) line - die struck. Finally, a Point & ID SEM Micrograph is performed showing the different Black and White (B&W) shaded areas of the selected SEM Micrograph and what metals or metal areas these spectrum areas constitute. In other words, the SEM/EDS apparatus in this case can target different B&W shaded regions of the SEM micrograph (i.e., microstructure area) and then determine which metals appear in these areas and these are classified as spectrum areas. Each area is numbered, and the associated metal assay results are displayed for each spectrum area.

At this point it will be instructive to discuss silvering of off-metal CCCs such as the case here as we examine the metal alloy profiles of Coins B & C. Investigations of the technology of surface silvering coin forgeries have been undertaken by many authors in the past (Darmstaedter 1929 (6); Campbell 1933 (7); Cope 1972(8); La Niece 1990(9), 1993(10)). Various manufacturing processes can be distinguished: (a) the mechanical attachment of a silver foil; (b) soldering, using a low melting point metal or alloy (tin, lead or silver–copper eutectic); (c) self-soldering, using diffusion between the silver foil (or powder) and the copper blank (Zwicker 1993(11); Anheuser and Northover 1994(12)); (d) coating with molten silver or alloy (Cope 1967; Anheuser and Northover 1994; Beck et al. 2005 (13)); (e) the application of chloride silver paste (Anheuser and France 2002 (14)); and (f) amalgamation with silver–mercury alloy (Vlachou et al. 2000) (15). Depletion silvering, also applied to silver coins, is not strictly a plating technique and has been studied in detail elsewhere (Cope 1972; La Niece 1990, 1993; Gitler and Ponting 2003 (16); Beck et al. 2003, 2004 (17); Butcher and Ponting 2005 (18). In our case here for these two coins B & C based on previous XRF results by this author and experience over the last three decades in this case it's "strictly" been an amalgamation process with a silver-mercury alloy type application at the coin's surface. In some cases, the instrument can identify mercury (Hg) and in some cases due to its low concentration levels, time constrictions and insufficient target areas of analysis no mercury is sometimes detected. In other cases, an efficient coin annealing process by the counterfeiter could be another cause for the absence of mercury and even too high an Instrument Detection Level (i.e., minimally 0.01% is recommended) may play a part in mercury's absence with silver (i.e.., amalgamation) at the coin's surface. When we see surface silvering on Kleeberg's or for that matter with GNL Counterfeit 8 Reales we are normally "almost always" expecting mercury to be the element present with silver unless the piece is silver plated. Even in the cases of silver plating or regal 8 Reales mercury is sometimes seen but in this case it's from the amalgamation of the silver ore refining process – a different matter altogether involving the presence of mercury (Hg).

Vlachou studied late Roman Coinage mercuric silvering, he indicated the silver-mercury amalgam process a paste was made up of silver and mercury. This paste was applied to the flan blanks which were then heated to boil off the mercury (boiling point 357ºC) leaving only a silver coating. This silver coating was extremely thin, under 10 microns thick (a micron is 1/1,000th of a millimeter) (19). The author feels this process and its general thickness has not changed much with time. Most mercuric amalgams seen on CCCs are thin and often not present in some areas due to their generic thinness and wearing away with time with normal circulation wear.

The last point to discuss prior to our sampling results is the presence of carbon and oxygen in the SEM/EDS results as the reader will see these two elements (i.e., called light metals) in most Map Sum Spectrums. What do the “individual” presence of carbon and oxygen in the assay results mean to the overall metal assay? To understand this concept, we need to understand patination and the formation of copper oxides and copper carbonates.

Metal objects, such as coins, that are buried for a long time or exposed to the atmosphere usually undergo patination - the formation of a patina. This is a reaction which changes the chemical composition, and usually color, of the coin’s surface in reaction to the environment. In fact, this process of patination occurs in any atmosphere and begins as soon as a coin is minted. Freshly made copper items first react with the air to form a brown copper oxide. The SEM/EDS is simply reporting the copper, or any other metal reported in the assay and oxygen “separately” with the oxides being formed on the coin’s surface. For carbonates the SEM/EDS results are reported as carbon and oxygen “separately” for any metallic carbonates being formed on the coin’s surface.

Patinas should not be confused with accretions. Accretions are external materials such as dirt, sand, clay, soot or grease that are stuck onto the coin. After centuries these accretions can become very hard and be difficult to remove. They differ, however, from patinas which are chemical reactions of the actual metal of the coin. Sometimes the line between the two can become blurred as the external adhesion products become mineralized and begin to chemically bond with the patina itself (20). We see both patinas and accretion materials in this study. These will be explained with each reported Map Sum Spectra in this paper.

Oxidization from the oxygen in the air or soil (or even in water) can cause the formation of red-brown cuprite (Cu2O) or of black tenorite (CuO). Oxidization usually leads to inert patinas (20). These oxides are not reported in the assays, just the cumulative amounts “within” of oxygen (O) within the oxides is reported.

Carbonization from CO2 and moisture in the soil can cause the formation of green or blue-green copper carbonate (CuCO3). While basic copper carbonate can form a very thin layer, it is essentially a crystallization process. Some copper carbonate products, such as bright green malachite (Cu2CO3Cu(OH)2), light blue azurite (Cu3(CO3)2(OH)2), or dark blue-green chalconatronite (NA2Cu (CO3)2·3H2O), can form thick layers of what are, under even low magnification, clearly crystals. Copper carbonate products are traditionally known as verdigris – a word that originally meant “the green of the Greeks” referring to the color of Greek bronze antiquities. Like oxidization, carbonization also usually leads to inert patinas (20). So, the carbon (C) being reported can be considered from metal carbonate compounds on the coin’s surface.

In some of the Map Sum Spectrums we reported also sodium (Na), potassium (K), calcium (Ca) and iron (Fe). These are common minerals found in the soil so their presence may be from some short-term burial or can also come from several centuries of normal handling. The presence of these elements is not considered part of the original metal assay.

The chloride reaction from chlorides and salts in the soil, plus humidity, can cause much more corrosive reactions. The most serious, and infamous, is the formation of the light green powdery “bronze disease”. Bronze disease is a self-sustaining chemical reaction where a powdery form of cuprous chloride (CuCl) further reacts with oxygen and moisture in the air, or in the coin itself, to form hydrochloric acid (HCl). The hydrochloric acid then reacts with the un-corroded copper to create more cuprous chloride, and the reaction thus continues (20).

Not all copper chloride reaction products are corrosive like bronze disease. Atacamite (Cu2(OH) 3Cl) is a bright green, though inert crystallization product which can make a copper-alloy item appear as if it were coated in bright green sugar (20).

Many of these patina-forming reactions cause the surface of the metal to expand to occupy a greater volume. This reaction can obscure the details of the coin’s surface. Some reactions, such as oxidization, can almost double the volume, while others, such as carbonization or chloride reactions can increase the volume of the affected area by four times or more. Such expansion due to patina-forming reactions can be easily confused with accretions. However, unlike accretions, which can often be mechanically removed, such reaction products may be much more difficult, or even impossible to mechanically remove. It is thus very important for those engaged in stabilization, cleaning or restoration efforts to understand the differences (20).

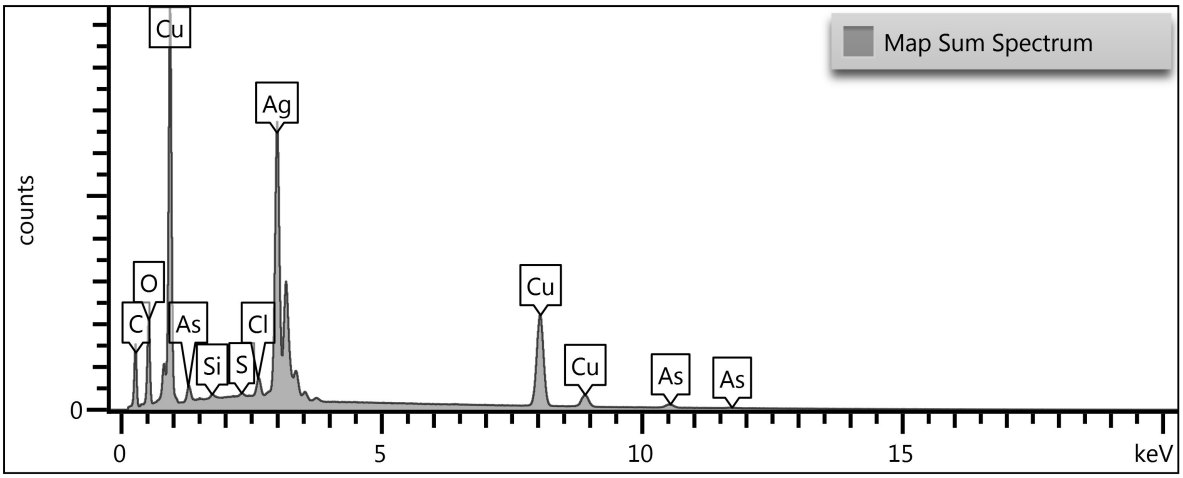
Different patinas can be found on the same coin due to differences in the surrounding soil, different humidity levels in the soil due to water flow, or differences in the internal metallic composition of the coin due to insufficient homogenization of the alloy during fabrication. Different patinas can also be found on the same coin in superimposed layers, for example alternating red and green layers of cuprite and malachite which may form due to differing conditions over time (20).

Based on this information of carbon and oxygen being reported separately due to the presence of oxide and carbonate formations with copper we also expect silver to also form oxides. As we proceed through the Map Sum Spectrums these results will be explained individually so the reader can understand more clearly all the metal results being reported and to more clearly assess if a metal is foreign to the coin or is part of its original make-up.

Analytical Results Coin B (Unpolished Surfaces)

We start the analytical results with Coin B with three random target areas in an unpolished state.

Coin B Target Area #1/#3 UNPOLISHED Surface Target Shot



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.73	0.00730	12.51	0.08	C Vit	Yes	
O	K series	1.66	0.00559	15.79	0.08	SiO2	Yes	
Si	K series	0.02	0.00018	0.16	0.01	SiO2	Yes	
S	K series	0.02	0.00021	0.13	0.01	FeS2	Yes	
Cl	K series	0.09	0.00075	0.44	0.01	NaCl	Yes	
Cu	K series	5.88	0.05876	31.34	0.08	Cu	Yes	
As	L series	0.28	0.00149	1.97	0.03	InAs	Yes	
Ag	L series	6.63	0.06630	37.67	0.08	Ag	Yes	
Total:				100.00				

Table 1: **Coin B**. See Figure 1. Kleeberg 19A-L37. **Target Area 1** of the first of three proposed target areas for Coin B's surface. **Map Sum Spectrum results of Target 1.** Target Area 1 shows high copper (Cu) over a possible silvered (Ag) surface. Chlorine (Cl) and sulfur (S) are environmental surface contaminants (25). Arsenic (As) is a foreign contaminant from the coin's manufacturing operation (24). Note the nearly equal portions of silver and copper in the assay. The high silver level possibly comes from a surface silvered wash operation. This coin may also be a debased silver coin with copper. This will prove easier in Phase II when the surface is polished/re-examined. Compare this to the regal 1802 Lima Peru Map Sum Spectrum in Figure 12-1. Note the silver value differences.

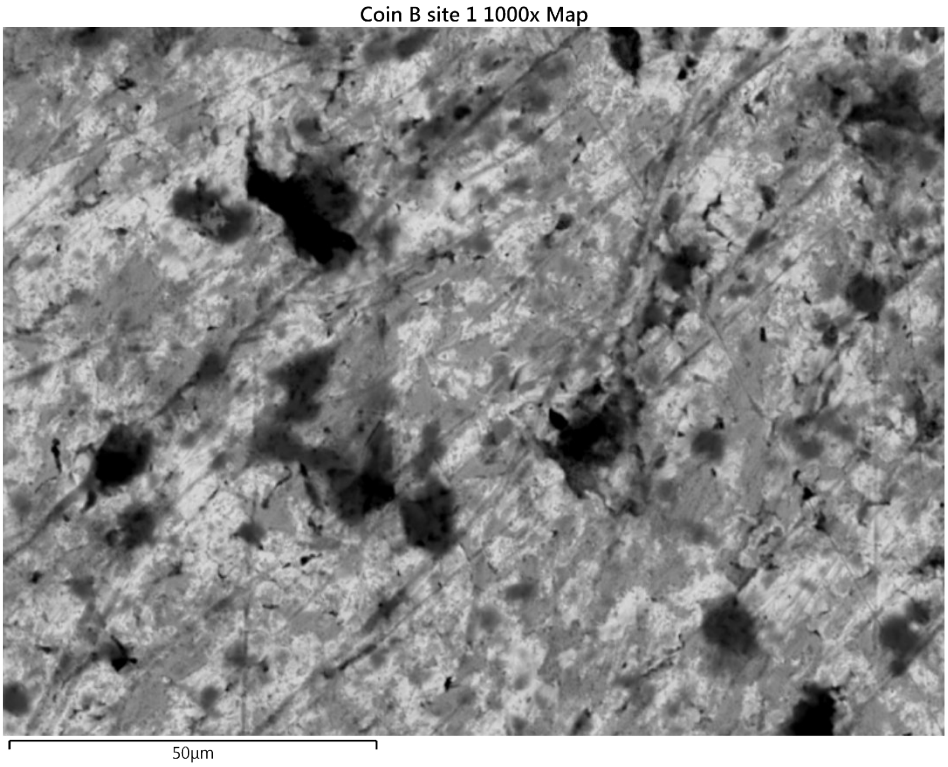


Figure 4-1: **SEM Micrograph of Coin B's Target Area 1** producing the metal assay results of Table 1 above of the same target area. **The magnification level here is 1000X**. The SEM micrograph shows a twin (grain) line microstructure and not being cast dendritic as also seen in the assay without traces of lead, tin and zinc normally associated with cast dendritic metal assays. A Point and ID of the different metal areas or the different shades of Black & White colorations in this SEM micrograph was performed as part of the three-tier SEM/EDS analysis and appears in the subsequent Figures 4-3, 4-4 & 4-5.

As an overview of this first target point - Figures 4-3, 4-4 & 4-5 are the three spectrum areas noted and circled (1, 2, & 3) in Figure 4-2 by the MSU analyst which were targeted and analyzed. Next an SEM micrograph area was reviewed to determine if the coin (Coin B) is cast/dendritic or twin line struck (Figure 4-1). Finally, a random target point was selected, and a full SEM/EDS analysis was recorded, and this is seen in Table 1. So, each coin (B & C) will have three target points which is why this first point of analysis is called Coin B Target Area 1. So, we have a Map Sum Spectra/SEM Micrograph/and a Point & ID analysis for each target point in this Phase I analysis. This is called the **three-tier SEM/EDS approach**. We have three target areas for both Coin B & C. As the reader proceeds through the data within this paper this will become clearer based on the descriptions and the data of each figure being presented.

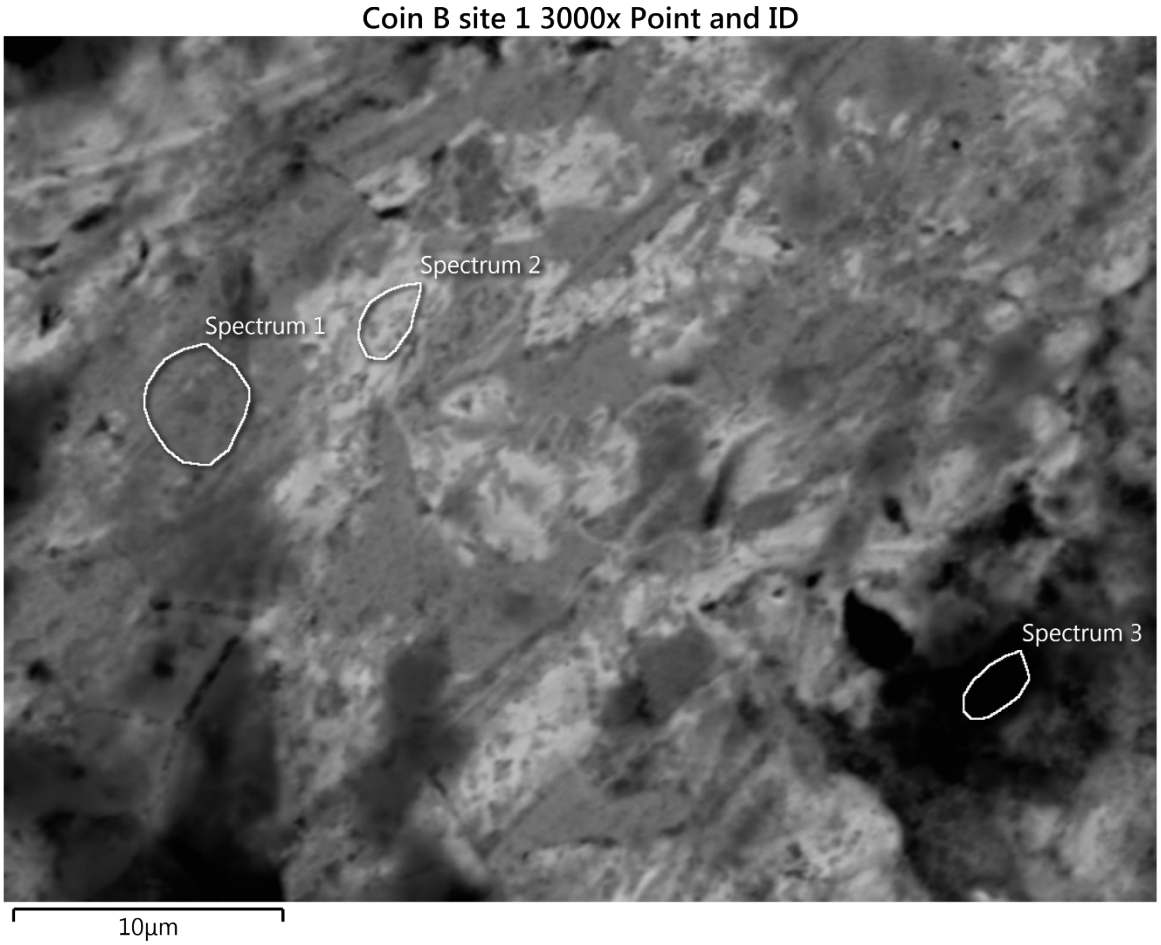


Figure 4-2. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. SEM Micrograph of Target Area 1 producing the metal assay results seen in Table 1 from a random target shot of Coin B's surface. The magnification level here is 3000X. **Spectrums 1, 2 & 3 were created from these different areas which are circled by the MSU analyst which constitute different shades of black & white imaging (as seen in the photo) representing different metal regions**. This Point & ID clearly shows in Figures 4-3-5 this could not be a 90% silver alloy due to levels of silver and other debased metals such as copper being abundant in the alloy mix.

When we view these Map Sum Spectrum and Point & ID spectrums for all three forthcoming Target areas, we can look at the metal assays and conclude this is anything but a 90% regal silver coin at all target areas. The author is not going to argue that a simplified XRF surface analysis is easier and more quickly informative to a coin's generic alloy to determine if its regal or counterfeit than this higher level of detailed Material Analysis being presented in this paper.

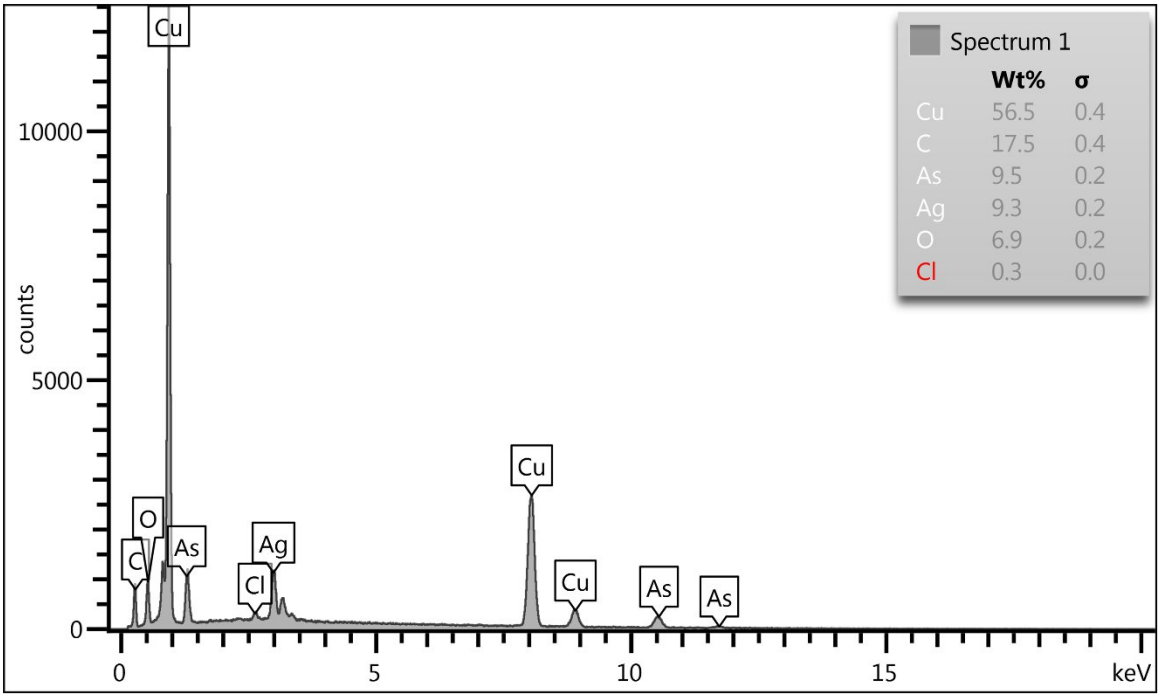


Figure 4-3. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 1 Area circled in Figure 4-2**. This area #1 of the SEM Micrograph as seen in the Spectrum assay in the top right area illustrates a high copper area with low silver. In other words, in this target area copper is the predominant metal as seen at 56.5%. Silver only at 9.3% which we can start to assume at this point being surface silvering and/or possibly a debased silver alloy with copper. This is also suggested by its previous XRF analysis and by its low weight compared to its regal listed weight in the KM Catalog of World Coins (24). Arsenic is a manufacturing residue picked up probably from ill-refined silver or copper ores during their purification (25). Further analysis with forthcoming data in this paper suggests it's probably from copper production. Chlorine is a common surface environmental contaminant (26). It should also be pointed out that rather than reporting in a wt.% of the total copper oxide such as (CuO) the individual elements and their abundances are reported separately as Copper (Cu) and Oxygen (O). So, if we were to add Carbon at 17.5% with Oxygen at 6.9% = 17.5 + 6.9 = 24.4. then subtract this value from 100. This yields 100-24.4 = 75.6. 75.6/100 = 0.756. We can then after factoring out carbon and oxygen since they are incorporated into these metals (elements) we can "roughly" through a normalization calculation calculate roughly that silver is at 9.3/.756 ~ 12.3% and copper is 56.5/.756 ~ 74.7%. This rough normalization calculation is under the premise that carbon and oxygen have obviously reacted with these other metals and formed specific chemical inorganic oxide compounds. This percentage of copper and silver could not produce these results in a 90% Ag/10% Cu regal specimen. We will see this more clearly when we analyze the 1802 Lima Peru regal two-reales coin depicted in Figure 3 above and examine its SEM/EDS data with this same testing strategy in Phase IV of this paper.

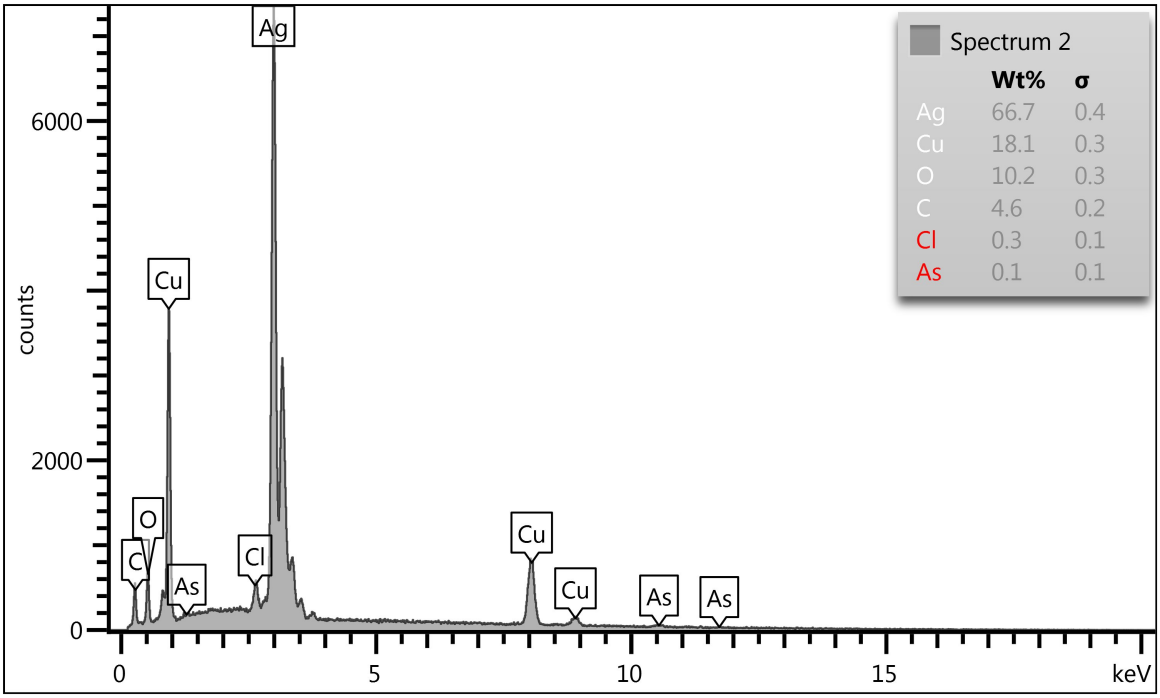


Figure 4-4. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 2 Area of Figure 4-2**. In this area of the spectrum is a high silvered area or possibly virtually targeting a silver particle of the silvered wash on this copper alloy piece or this could be a silver area as part of this overall silver coin being debased with copper. Copper here is lower than in Spectrum 1, but silver is higher at 66.7% but not even close to a regal silver value of 90%. We again see Arsenic (As) as a manufacturing contaminant from a geological ore source and probably from poor copper ore mining/refining (25) and chlorine being again the commonly seen environmental surface contaminant (26).

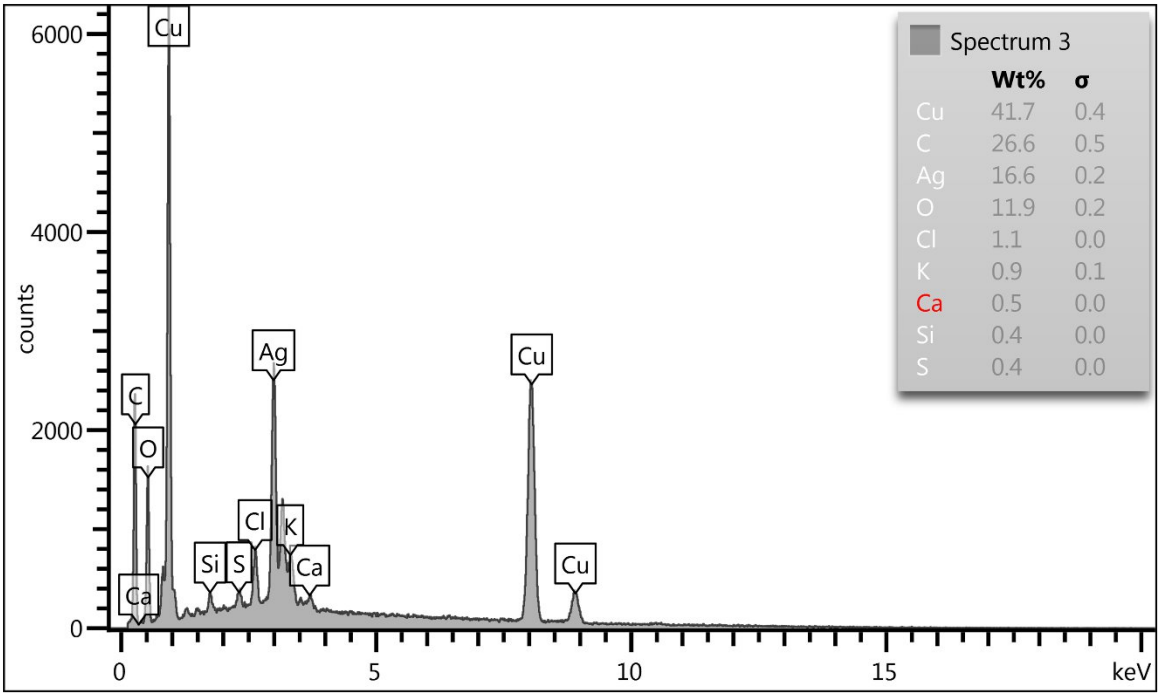
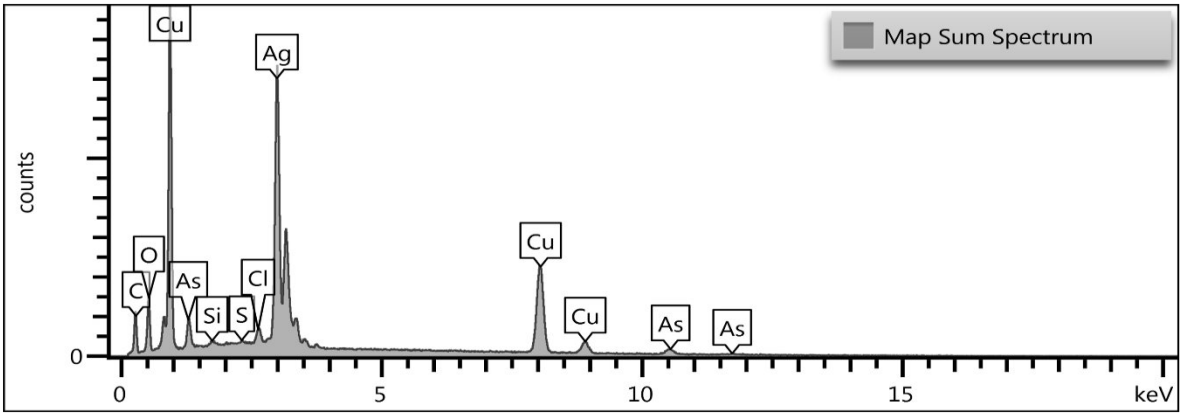


Figure 4-5. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 3 Area of Figure 4-2.** In this spectrum we see our two principal components from the unpolished surface target shot. Specifically, the surface silvering or debased silvering and the copper host coin or copper being the main debasement material for silver. We see high copper at 41.7% and the silver level is low again as seen in Spectrum 1 (Figure 4-3). Note the value of the copper wt.% being almost "three times" the value of the silver – an impossibility in a regal 90% Ag coin where Cu is generally <10%. We are seeing more so-called surface contaminants on the surface of this final Point & ID spectrum area such as potassium (K), calcium (Ca), silicon (Si) and sulfur (S) suggesting a more soiled surface. From my experience the two most common surface contaminants are indeed chlorine and sulfur. Arsenic, when present in many cases, when it is seen at levels > 1% suggests a cruder manufacturing process and higher sulfur levels will be generated in the analysis. This author has seen for example higher sulfur levels in Pre-Confederation State Coppers such as New Jersey, Connecticut & Vermont Coppers when compared for example to even English imported contemporary circulating counterfeits which are crudely produced such as Evasion Coppers produced in England. It's simply how efficient was the annealing process of copper ingots and the subsequent manufacturing process that dictated sulfur levels in these 17thC/18thC copper coin metal assays. The cruder the process the higher the sulfur levels present in the assay. Not a definitive provenance tool such as lead isotopic analysis but a good starting point to a coin's origin in the opinion of this author (20).

This concludes Coin B's Random Target Area #1 analysis.

Coin B Target Area #2/#3 Unpolished Surface Target Shot: **Table 2 Map Sum Spectra**



Element	Line Type	Apparent Concentration	k Ratio	Wt.%	Wt.% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.41	0.00411	9.57	0.25	C Vit	Yes	
O	K series	0.88	0.00298	11.28	0.23	SiO2	Yes	
Si	K series	0.02	0.00015	0.18	0.04	SiO2	Yes	
S	K series	0.02	0.00015	0.12	0.04	FeS2	Yes	
Cl	K series	0.05	0.00041	0.31	0.04	NaCl	Yes	
Cu	K series	4.84	0.04838	32.66	0.25	Cu	Yes	
As	L series	0.45	0.00241	4.15	0.14	InAs	Yes	
Ag	L series	5.69	0.05693	41.71	0.26	Ag	Yes	
Total:				100.00				

Table 2 (above). Map Sum Spectra Coin B Target Area 2 illustrates a similar overview of Target Area 1's Map Sum Spectra in which we see a low silver/very high copper assay as compared to

a regal silver issue of 90% silver. Chlorine (Cl), Silicon (Si) and sulfur (S) are surface contaminants and arsenic's (25) presence normally due to copper ore manufacturing with a value of 4.15% being very high suggesting a crude manufacturing operation as in a crude counterfeiting operation. Copper and silver are almost equal in their weight percentages. **The results of Table 2 are from a single random target area of Coin B's surface.** Compare this to the regal 1802 Lima Peru Map Sum Spectrum in Figure 12-1 and compare the silver values.

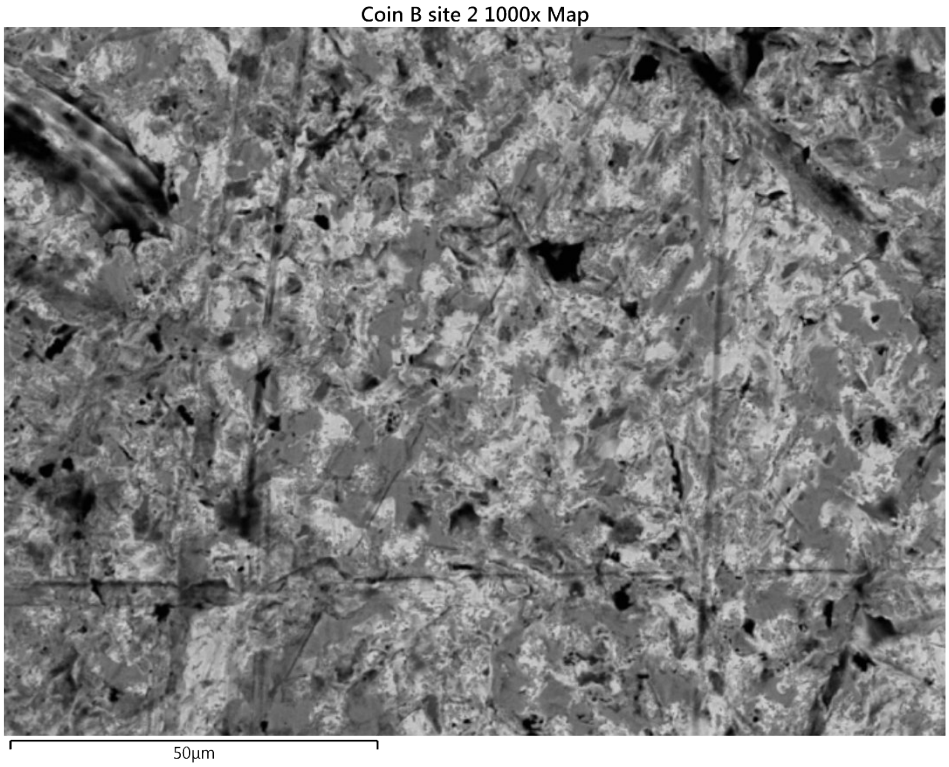


Figure 5-1: **SEM Micrograph of Target Area 2** producing the metal assay results of Table 2 from a single target area. The magnification level here is 1000X. The SEM micrograph shows a twin line microstructure and not being cast dendritic as seen in the assay without traces of lead, tin and zinc normally associated with cast dendritic metal assays. A Point and ID of the different metal areas or different shades of Black & White colorations in this SEM micrograph was performed as seen previously in Target Area #1 and these MSU selected different shaded B & W spectrum areas appear below in Figure 5-2 with the spectrum results respectively provided in Figures 5-3, 5-4 & 5-5.

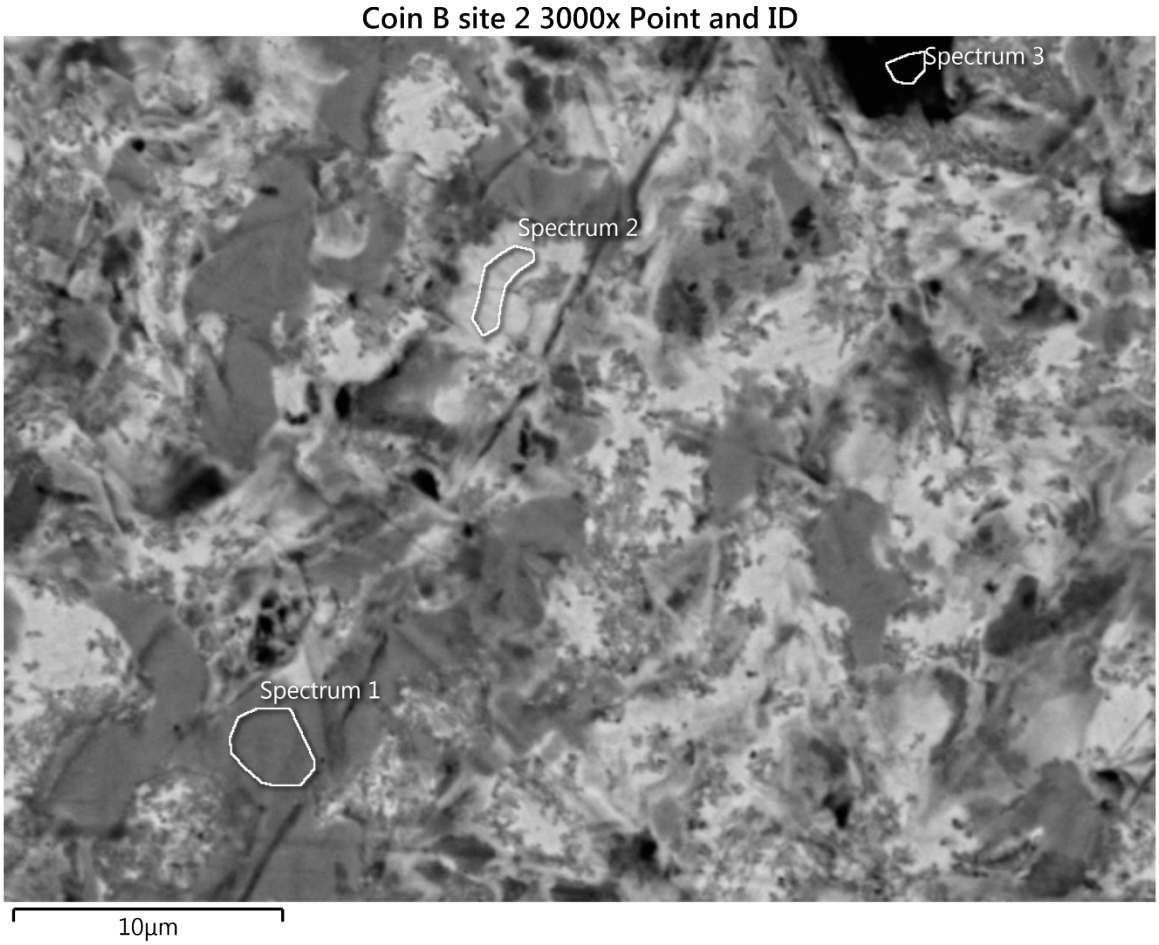


Figure 5-2. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **SEM Micrograph of Target Area 2**. The magnification level here is 3000X. Spectrums 1, 2 & 3 were created from these different areas which are circled which constitute the different shades of Black & White imaging representing different metals or different metal alloy mixture areas. This Point & ID clearly shows as in Target Area 1 this could not be a 90% silver alloy due to the levels of silver and the non-precious metal copper being very abundant in the alloy mix.

When we view these Map Sum Spectrum for this Target Area #2, we can see conclusively looking at the metal assays this is anything other than a 90% regal silver coin. The author is not going to argue that a simplified “singular” XRF surface analysis is easier and more quickly informative to a coin’s generic alloy or if its regal or counterfeit but it’s never advisable to take the quantitative numbers to be extremely accurate but just a generic alloy type should be concluded with an XRF analysis on a numismatic item particularly with an analysis of an unpolished surface. In this case Coin B being a silvered surface high copper (Cu) alloy or possibly a heavily debased silver issue with copper.

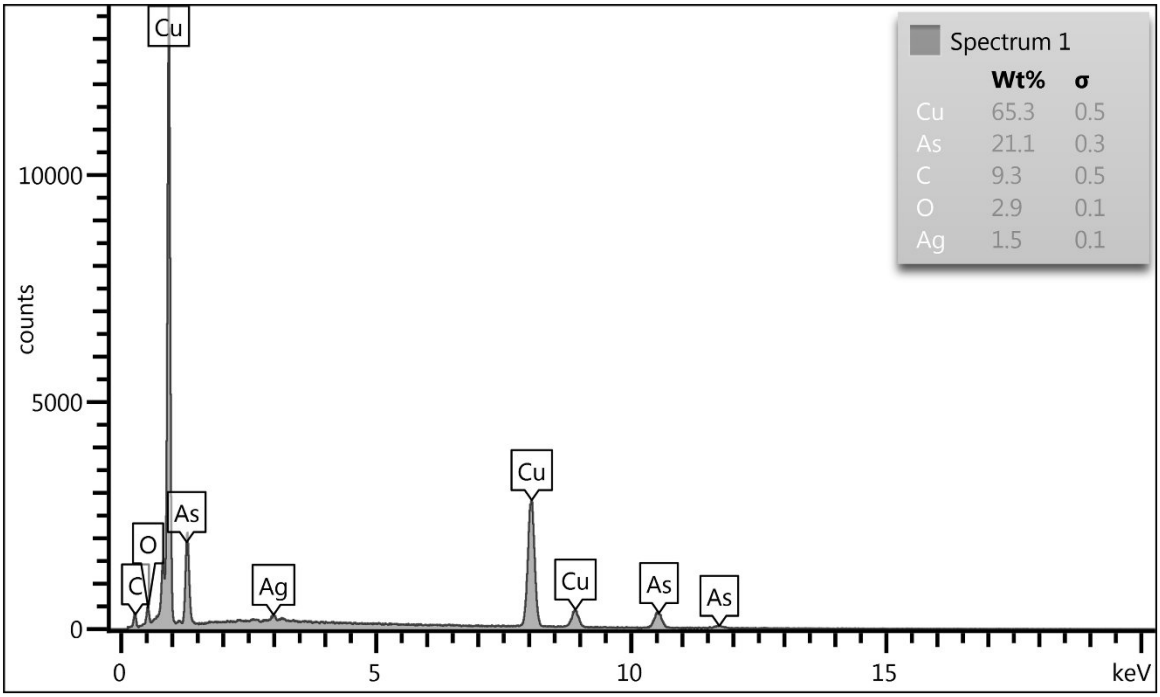


Figure 5-3. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 1 Area of Figure 5-2. Target Area #2**. This area of the SEM Micrograph illustrates a very high copper area with very low silver being present. In other words, in this target area copper is the predominant metal as seen at 65.3%. Silver only at 1.5% which we know at this point being only surface silvering or a heavily debased silver host coin with copper. The coin's weight to regal weight at 6.775 grams being very low already suggest its non-regal status. Arsenic is a manufacturing residue picked up probably from ill-refined copper ores during its purification and in this spectrum with arsenic being so high as is copper this seems to be the source for high arsenic rather than from silver production (25). So, with this very high arsenic value we can probably assume that the appearance of arsenic in the (Map Sum Spectrum) for Coin B is probably coming strictly from the copper as a carry-over contaminant from its production process of copper ingots to coin blanks in this manufacturing counterfeit operation. The other point of consideration we need to ask ourselves "Do we really consider it possible that arsenic could achieve this quantitative level in the assay in a regal type of operation or more likely encountered in a counterfeiting operation?" With an arsenic (As) Point & ID value of 21.1% the answer should be obvious.

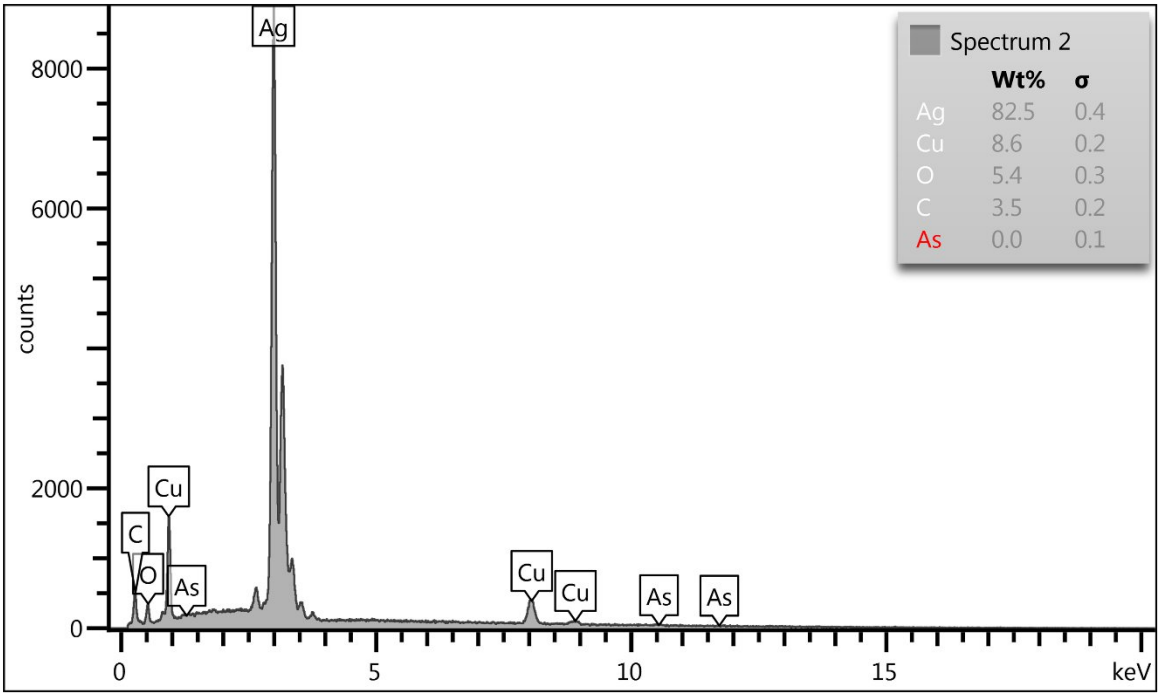


Figure 5-4. **Coin B**. **Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 2 Area of Figure 5-2**. This area of the SEM Micrograph illustrates a high silver level with this area more than likely being a silver particle or silvered area of the surface silver wash or a silver area of a highly debased silver host with copper. The only other metal detected in the region is copper. We must remember we are shooting target areas of an unpolished coin so silver particles of the overall silvering are random on the surface and with that occurrence we simply do not see high silver in the other target areas near the regal level of 90%. Furthermore, the Map Sum Spectra metal assay in Table 2 shows nothing close to a 90% Ag regal two-reales as its illustrating a metal assay with equal amounts of copper & silver. Note here the total absence of arsenic when compared to Spectrum 1. So more conclusive proof that its copper creating this high contaminant arsenic level in the assay of Coin B and not the silver. Probably some form of high arsenical copper as one possible copper source for this counterfeiting operation. Compare this Map Sum Spectrum to the Phase IV Map Sum Spectrum of the regal two reales 1802 Peruvian Lima coin with its 90% Ag value in Figure 12-1 and then compare the silver values.

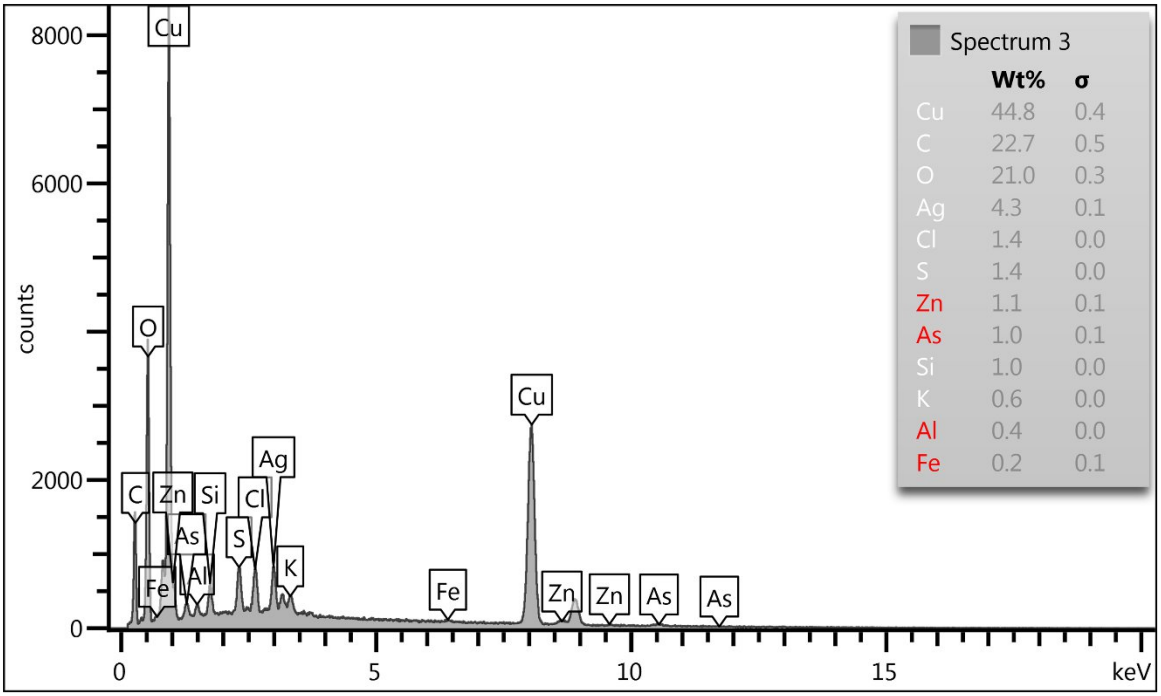
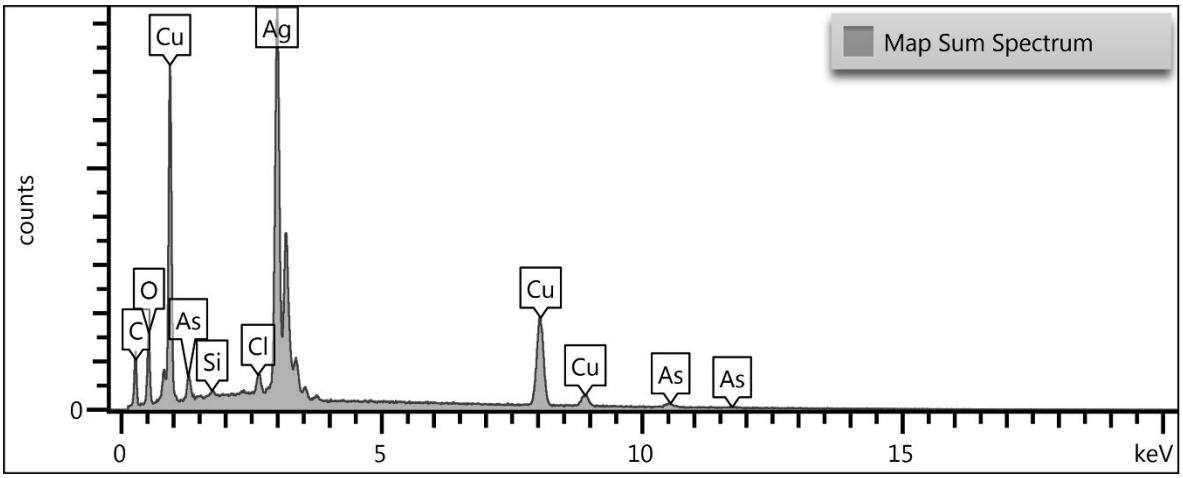


Figure 5-5. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 3 Area of Figure 5-2**. This area of the SEM Micrograph as seen in the spectrum assay at the top right illustrates a wide array of metals. We see the high copper, low silver from the surface silvering or silver debasement with copper. The chlorine (Cl), sulfur (S), silicon (Si), potassium (K), aluminum (Al) and Iron (Fe) all being surface contaminants. Iron (Fe) however can sometimes also be a geological ore contaminant. Trace arsenic (As) as seen in other spectrums being a manufacturing ore contaminant is also present at 1.0% and as previously discussed from the presence of copper (25). Interestingly we pick up trace Zn which may suggest this is a low zinc brass host and not just a high copper host coin. When we review the polished target area results in the upcoming Phase II section in this paper this will of course provide a clearer view of the true composition of Coin B and its "true" base alloy when the possible surface silver layer and outside contaminants (i.e., both soil and air) are removed by coin surface polishing.

Coin B. Target Area #3/#3. UNPOLISHED Surface Target Shot.

As previously discussed, both coins for analysis Coins B & C were each given three random target area shots with SEM/EDS. Within each Target area we created a Map Sum Spectra, a SEM Micrograph to determine if cast dendritic or twin line struck and a three-four Point & ID area chosen in the different black and white shaded regions of the SEM micrograph which represent different metal regions. This is the last target area (**Target Area #3**) before proceeding to Coin C. To remind the reader in Phase II we will look at Coin B & C's polished SEM/EDS results. This will be after Coin C's unpolished three target areas surface results. **We will now examine Coin B's final target area (Target Area #3) in Table 3 below on the next page.**



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.42	0.00423	8.75	0.22	C Vit	Yes	
O	K series	0.94	0.00316	12.83	0.24	SiO2	Yes	
Si	K series	0.02	0.00017	0.19	0.04	SiO2	Yes	
Cl	K series	0.05	0.00046	0.34	0.04	NaCl	Yes	
Cu	K series	4.01	0.04006	27.35	0.24	Cu	Yes	
As	L series	0.30	0.00157	2.67	0.12	InAs	Yes	
Ag	L series	6.56	0.06558	47.86	0.27	Ag	Yes	
Total:				100.00				

Table 3. Coin B. Map Sum Spectrum. Target Area #3. A lower level of copper than silver but only 20% lower in these table results not equating to a 90%Ag/10% Cu regal issue. Silicon (Si) & chlorine (Cl) being surface contaminants and arsenic (25) as discussed earlier a carry-over contaminant probably from copper production or ill-refined copper a common practice seen in counterfeit copper operations. Compare again this assay to the regal 1802 Lima Peru Map Sum Spectrum in Figure 12-1 and the difference in silver levels.

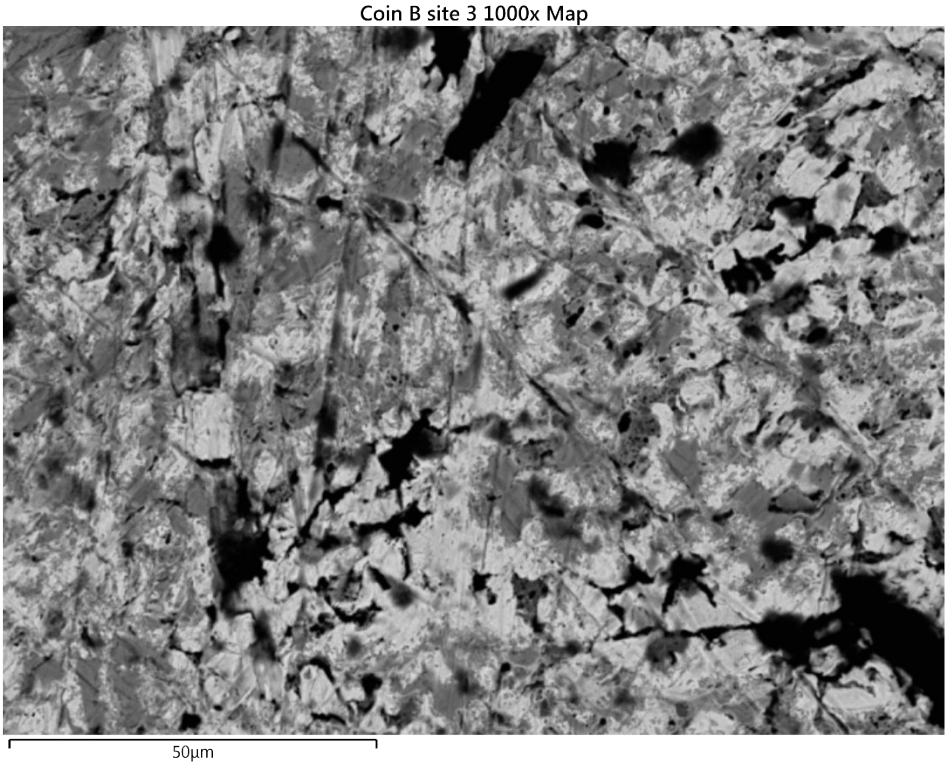


Figure 6-1: **Coin B. SEM Micrograph of Target Area 3**. The magnification level here is 1000X. The SEM micrograph shows a twin line microstructure and not being cast dendritic as also seen in the assay without traces of lead, tin and zinc normally associated with cast dendritic metal assays. Note the definitive twin line microstructure with long striation lines and the overall jigsaw like pattern. A Point and ID of the different metal areas or different shades of Black & White colorations in this SEM micrograph was performed as seen previously in Target Area #1 and appears below in Figures 6-2 with the Point & ID spectrum results respectively seen in Figures 6-3, 6-4 & 6-5.

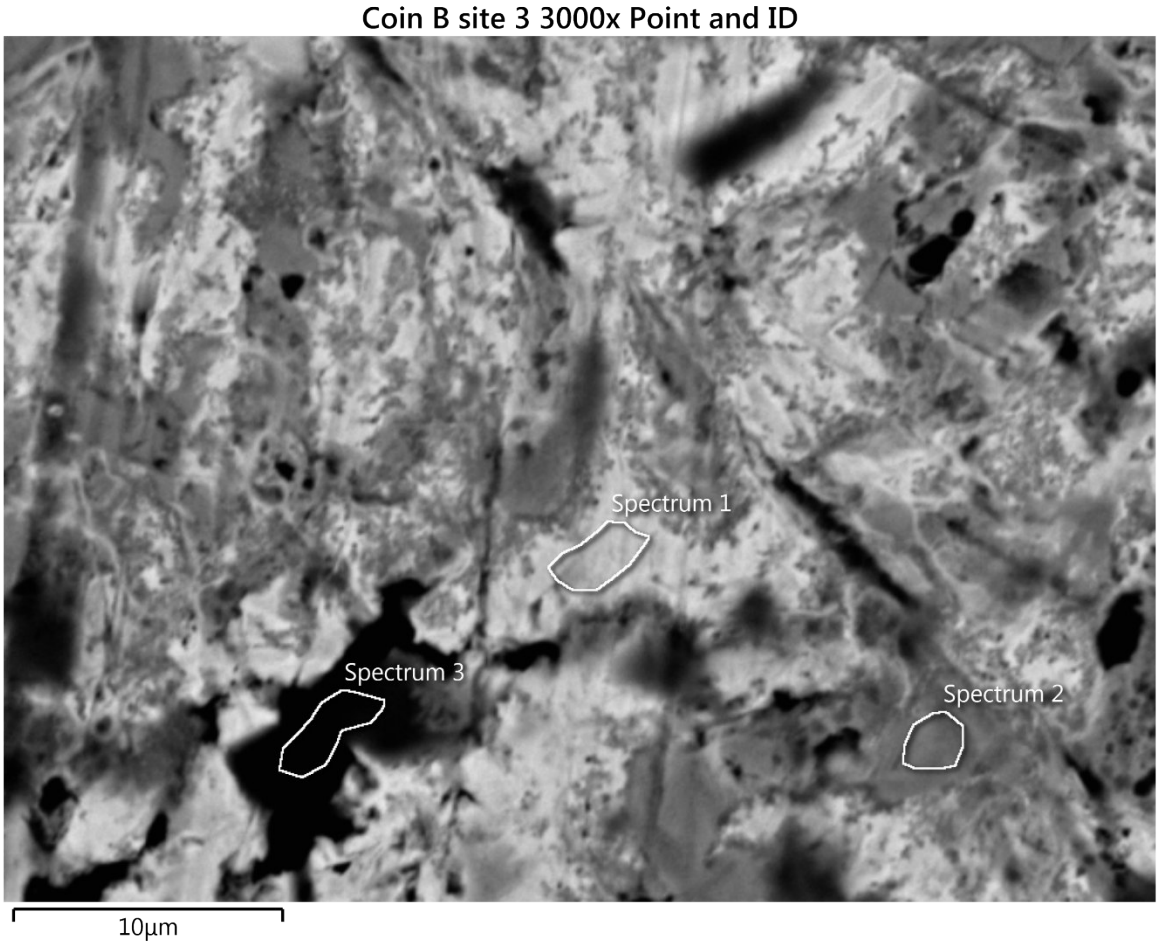


Figure 6-2. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. SEM **Micrograph of Target Area 3.** The magnification level here is 3000X. Spectrums 1, 2 & 3 were created from these different areas which are circled which constitute different shades of black & white imaging representing different metals and/or metal alloy mixture areas. This Point & ID clearly shows as in Target Areas 1 & 2 this could not be a 90% silver alloy due to consistent low levels of silver and the non-precious metal copper being highly abundant in the alloy mix. Again - In these different spectrum areas seen here (Spectrum Areas 1, 2 & 3) give you further specific metal assays in the different shaded black and white regions of the SEM Micrograph.

When we view these Map Sum Spectrum for all three Target areas, we see conclusively the metal assays are generally a silvered surface high copper alloy or a high silver debasement with copper alloy for all three Target area. This is due to the “many” areas showing low silver and very high copper and no silver (Ag) quantitative levels being near 90% Ag. Again, compare these results to the Phase IV results of the 1802 Peru Lima regal 90% silver coin and specifically in the Map Sum Spectrum illustrated in Figure 12-1. Compare the silver levels to this regal specimen.

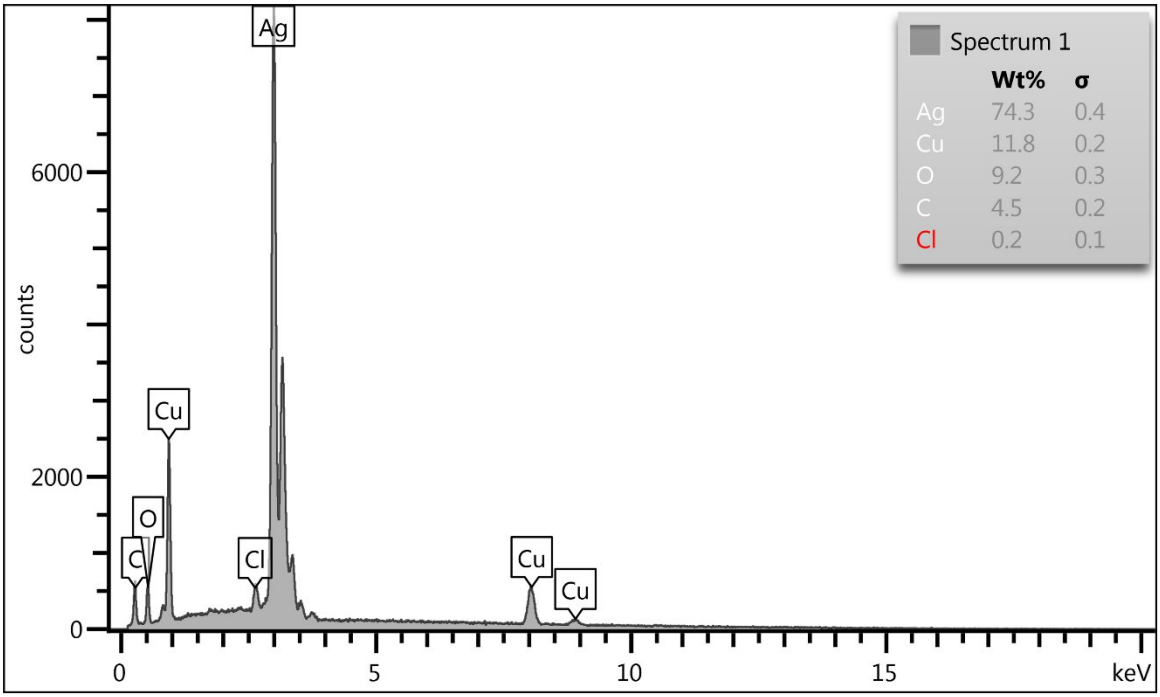


Figure 6-3. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 1 Area of Figure 6-2. Target Area #3.** This area of the SEM Micrograph as seen in spectrum assay at the top right illustrates a very high silver area with very low copper. In other words, in this target area silver is the predominant metal seen at 74.3.3%. Copper only at 11.8% which indicates this region is picking up a silver particle or silvered area in the silver wash along with some adjacent copper oxide particles or this is from a high debased silver with copper coin assay. Chlorine (Cl), as noted many times before being a surface contaminant predominantly from atmospheric water vapor which contains salt (chlorides) in the mix originating from seawater and other possible airborne contaminants from pollution sources.

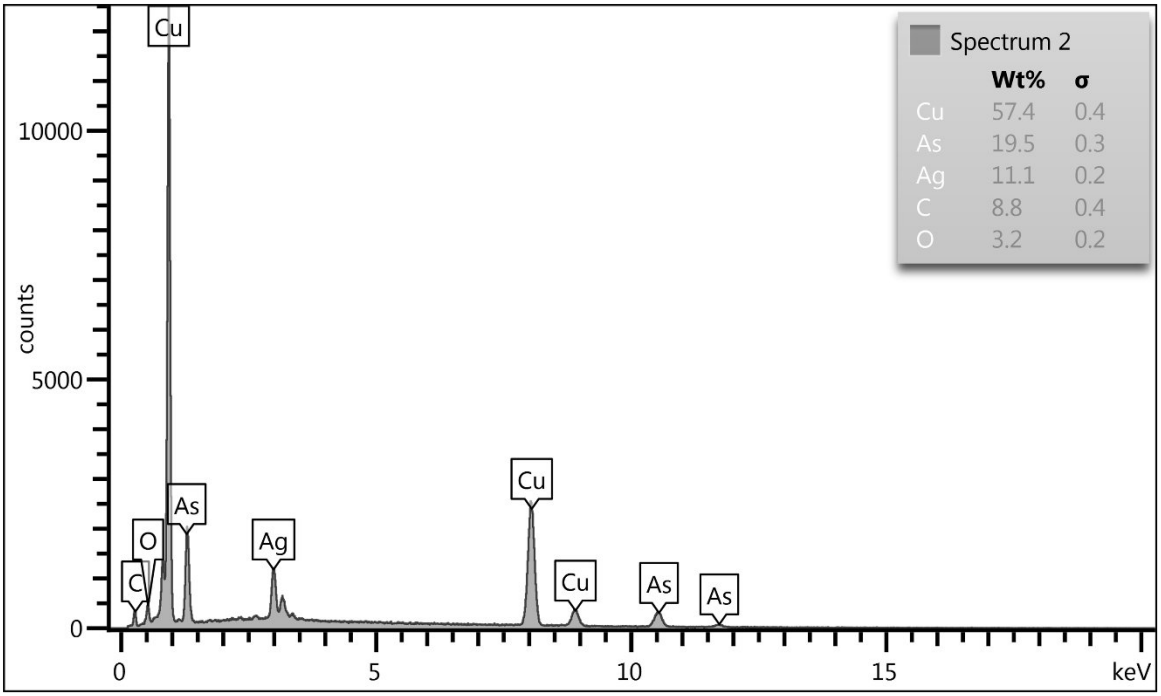


Figure 6-4. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 2 Area of Figure 6-2. Target Area #3.** This area of the SEM Micrograph as seen in spectrum assay illustrates a very high copper area with very low silver at 11.1%. Again, as previously seen with high copper spectrum regions this high level of copper we also see a proportionally high level of arsenic probably from poor (i.e., unsophisticated) copper production/refining operations (25). This level of arsenic does suggest a crude operation of copper annealing often seen with counterfeit production operations based on the author's previous experience with arsenic levels being higher in more crude manufacturing operations (21). As previously mentioned, and with more forthcoming Material Analysis testing expect higher levels of sulfur in Pre-Confederation State Coppers of the 18th Century than coins produced in England such as Evasions, Conder Tokens and even George III 1775 CCC Halfpence. The cruder the operation in general the poorer the annealing of copper ingots resulting in higher amounts of detectable sulfur. Not really a provenance tool but overall, a "good initial indicator" of a coin's probable manufacturing source whether products of pre-Confederation America or imported from England whether a contemporary circulating counterfeit or regal (21).

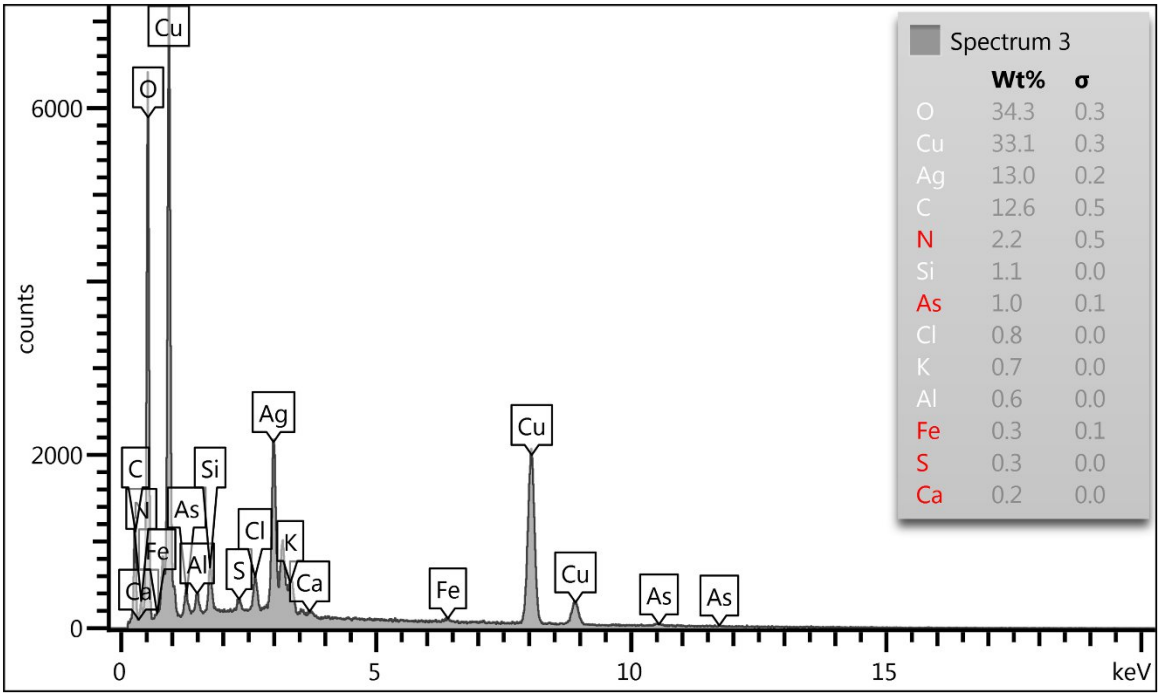


Figure 6-4. **Coin B. Point & ID SEM Micrograph**. Coin B is illustrated in Figure 1. K.19A-L37. **Spectrum 3 Area of Figure 6-2. Target Area #3.** This area of the SEM Micrograph as seen in the spectrum assay certainly illustrates a very high mix of metals. We have seen this before with silicon (Si), arsenic (As), potassium (K), aluminum (Al), Iron (Fe), sulfur (S) and calcium (Ca) being contaminants with sulfur and chlorine being common surface contaminants and iron which can be either from an environmental or manufacturing contaminant source as it's a commonly encountered in ore production due to its universal presence in many geological ore sources. Note the copper level here being more than twice the silver percentage. The oxygen level is undoubtedly high here at 34.3% since as explained earlier its simply forming oxide compounds with these other reported metals in this spectrum analysis - copper (Cu), silver (Ag), nitrogen (N), silicon (Si), arsenic (As) potassium (K), aluminum (Al), iron (Fe), and calcium (Ca). The carbon (C) forming carbonates.

Overview of Coin B's Composition

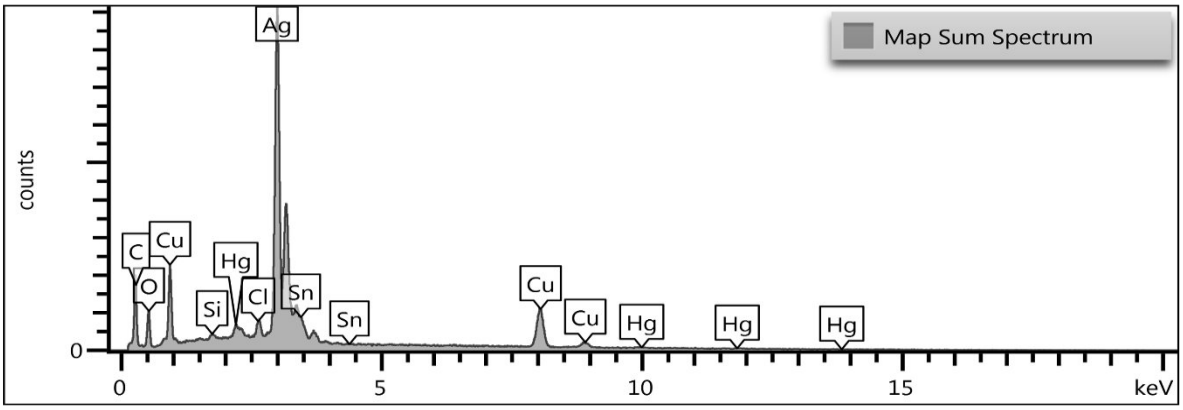
The results of the Map Sum Spectrum of Targets 1, 2 & 3 along with the Point and ID spectrums within each of the three target areas do not suggest a regal 90% Ag coin as no silver levels came close to this quantitative value. This is why as confirmation a legitimate (regal) two reales will also go under the same scrutiny of analysis for comparison purposes. Coin B's SEM Micrographs do not show dendritic cast microstructure profiles from any noted literature references such as Scott (22). The author in the Phase III section will display a common dendritic cast profile from Scott for comparison purposes. Coin B is either a surface silvered copper host or is a heavily debased silver alloy with copper type host. A review of the polished results for Coin B in Phase II will confirm which of these two possible CCC scenarios is more likely.

Phase I Coin C Unpolished Analytical Results for Target Areas 1-3

Introduction

As with Coin B we now proceed to the second coin for analysis. Coin C of the same variety as Coin B but of a different metal assay composition based on my preliminary XRF results prior to the MSU SEM/EDS three-tier analysis. As with Coin B we will perform a Map Sum Spectrum of three random target areas. Create SEM Micrographs to determine if the coin is cast dendritic or twin line struck in each target area and finally do a Point & ID of the three-target areas from the SEM Micrographs and select spectrum areas for metal assay determinations based on the different appearance of the black & white shaded regions within this SEM micrograph as previously done with Coin B. Since both coins are of the same die variety (K.19A-L37's) and hence from the same manufacturing location will we find a similar manufacturing method? Coin B turns out to be more likely a debased silver alloy with copper since no mercury was detected after three target area searches on Coin B's surface. The silvering seen on the surface by eye for Coin C may provide a different picture with the presence of mercury being detected from the author's initial XRF analysis performed in a vacuum chamber. This analysis indicating an amalgamation type process of applying silver to the surface with mercury and then burning off the mercury but as in most cases never fully removed by annealing which therefore leaves a delicate thin film of mercuric silvering on this off-metal (i.e., non 90% silver) contemporary circulating counterfeit. We will also look for surface contaminants such as sulfur (S), chlorine (Cl) and arsenic (As) which was almost universally seen on Coin B's surface when copper was present. As with Coin B – Coin C will be compared to the regal silver coin pictured in Figure 3 an 1802 Lima Peru two-reales and will also compare these results to a polished section of Coin C at the rim area. With most surface contaminants removed what does the host coin metal assay tell us at this point? What will the regal coin analysis tell us when compared to Coin C's results? How will the cast and struck microstructures of these George II/III cast and struck halfpence compare to our two real contemporary circulating counterfeits B & C? Questions which will all be answered as we proceed now with the triple-tier SEM/EDS full profile analysis of Coin C the other K.19A-L37 variety test specimen.

Table 4: **Coin C** Kleeberg 19A-L37 Map Sum Spectrum



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.70	0.00701	11.67	0.23	C Vit	Yes	
O	K series	0.62	0.00207	10.30	0.25	SiO2	Yes	
Si	K series	0.03	0.00021	0.23	0.04	SiO2	Yes	
Cl	K series	0.06	0.00053	0.41	0.04	NaCl	Yes	
Cu	K series	2.20	0.02203	15.96	0.21	Cu	Yes	
Ag	L series	7.21	0.07213	55.07	0.32	Ag	Yes	
Sn	L series	0.46	0.00461	4.37	0.17	Sn	Yes	
Hg	M series	0.25	0.00230	1.98	0.19	HgTe	Yes	
Total:				100.00				

Table 4: **Coin C**. Kleeberg 19A-L37. **Map Sum Spectrum**. **Target Area #1**. A coin like Coin B but in this case the silvered area on the surface has detected mercury (Hg). So, this regal looking example has a typical mercuric silvering wash on the coin's surface placed upon a low tin bronze (Cu/Sn) type alloy seems to have already been determined with this single target point analysis! Tin (Sn) is at 4.37%, a percentage clearly indicating it was added into the metal mix and not an ore contaminant level which from my experience is normally <1%. The surface silvering is heavy in this example (55.07%) which can be seen also with the elevated mercury value detected at the surface at 1.98% (i.e., very high for Hg) and the silvering can be seen visually with coin in hand under no magnification. Silicon (Si) and Chlorine (Cl) being typical surface contaminants. Compare this to the regal 1802 Lima Peru Map Sum Spectrum in Figure 12-1 and compare the silver levels.

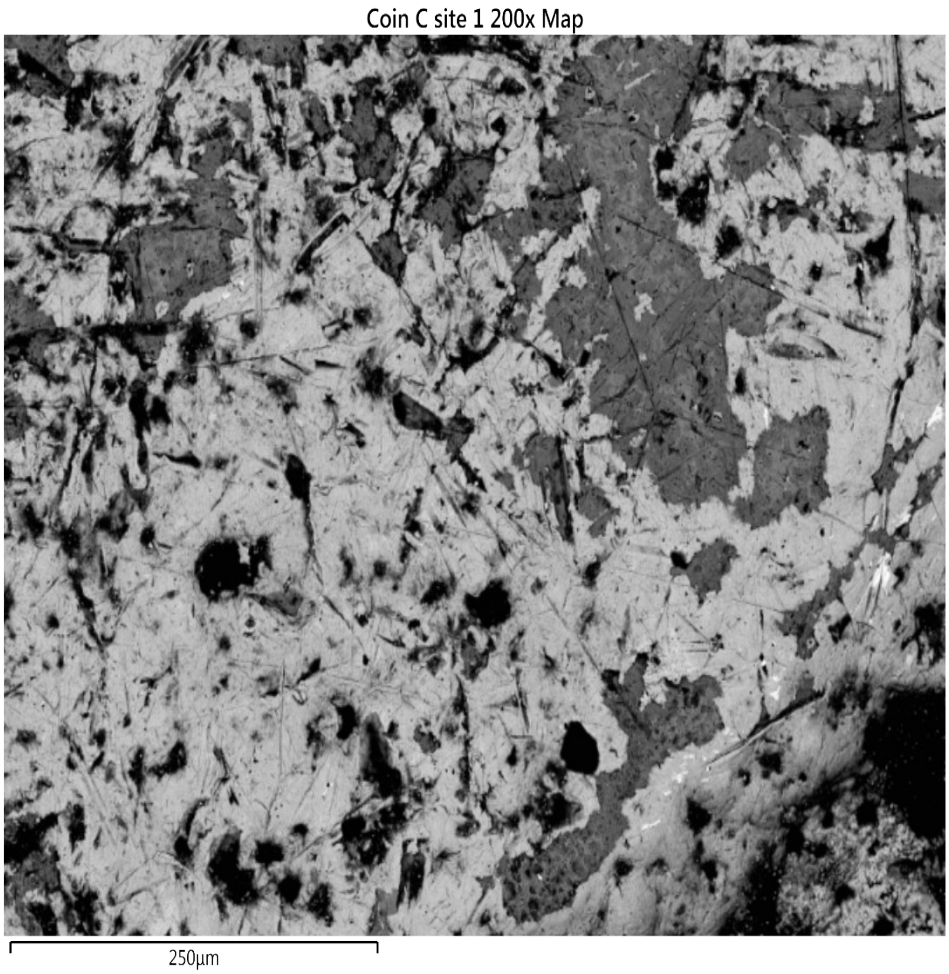


Figure 7-1: **Coin C. SEM Micrograph of Target Area #1**. The magnification level here is 200X. The SEM micrograph showing a twin line microstructure and not being of a cast dendritic microstructure as seen in the assay without traces of lead normally associated with cast dendritic metal assay (i.e., such as a bronze leaded alloy). We see straight line striations and many areas showing a jigsaw like pattern at this magnification level of 200X diagnostic of a die struck microstructure. A Point and ID of the different metal areas or different shades of Black & White in this SEM micrograph was performed and appear below in Figures 7-3, 7-4, 7-5 & 7-6. The spectrum areas selected by the MSU analyst are seen in Figure 7-2 but on a SEM Micrograph magnification level of 1000X which allowed a better selection process of the different shaded areas indicating different metals and/or different metal alloy regions.

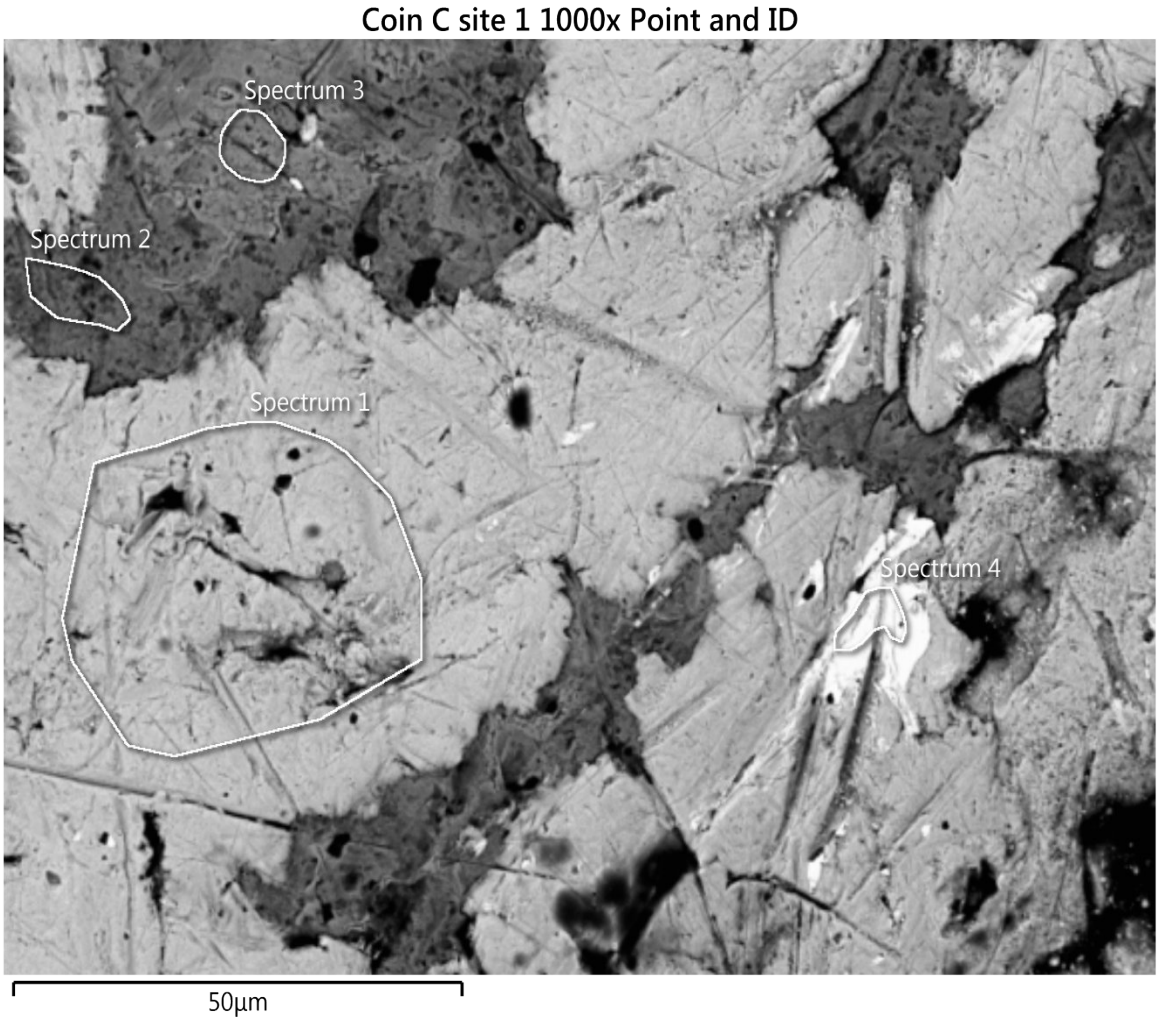


Figure 7-2. **Coin C**. Point & ID SEM Micrograph. Coin C is illustrated in Figure 2. K.19A-L37. SEM Micrograph of **Target Area #1**. The magnification level here is 1000X. Spectrums 1, 2, 3 & 4 above were chosen from these different areas which are circled which constitute different shades of black & white imaging representing different metal regions or different metal alloy mixture areas. This Point & ID clearly shows this could not be a 90% silver alloy due to levels of silver and other non-precious metals such as copper being abundant in the alloy mix. Compare this to the Point & ID done for the regal silver 1802 Lima Peru Coin in Phase IV (Figure 12-4).

When we view the Map Sum Spectrum of a random target area, we can see conclusively looking at the metal assay this is anything other than a 90% regal silver coin. Note the “distinctive” jigsaw patterns at this magnification level indicating a die struck microstructure mentioned earlier in Figure 7-1 at this higher magnification level at 1000X when compared to 200X for Figure 7-1.

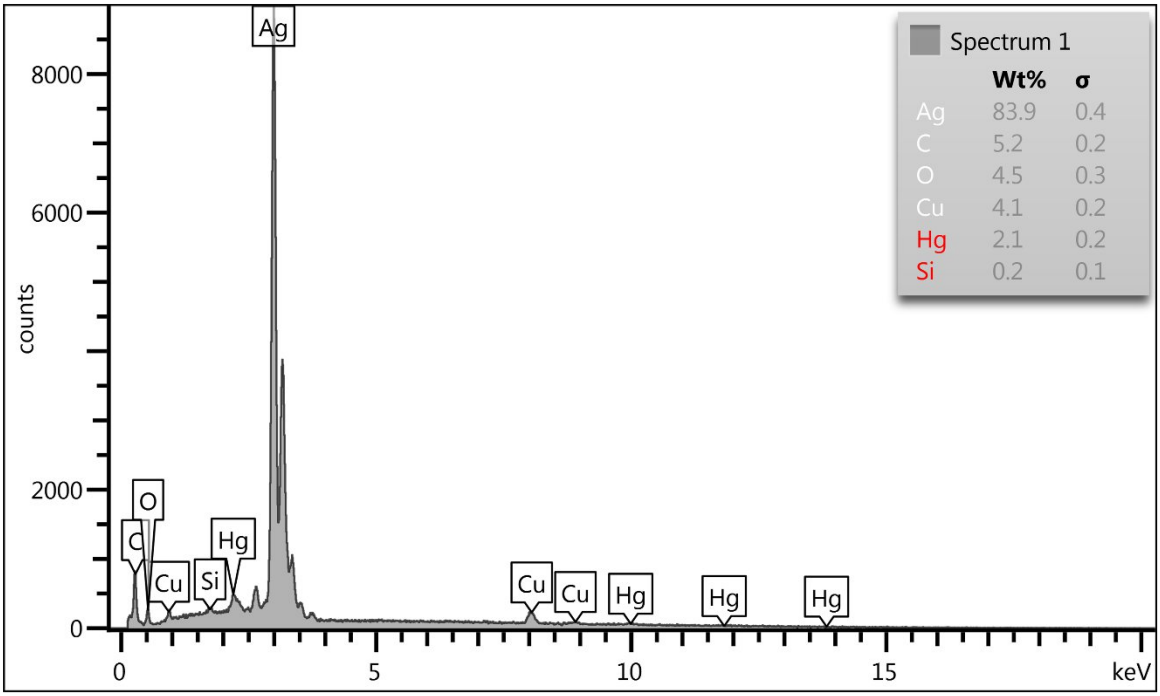


Figure 7-3. **Coin C. Point & ID SEM Micrograph**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 1 Area of Figure 7-2. Target Area #1**. This area of the SEM Micrograph as seen in the spectrum assay at the top right of this figure indicates a very high silver area probably targeting a silver particle or silver area as part of the mercuric silver wash. We see low copper in the region along with mercury at a very high level (2.1%) on the surface confirming the silver is part of a mercuric silver amalgamation wash on Coin C's surface and not part of a regal alloy composition. Silicon (Si) is a surface contaminant. In this case, the mercury was not properly burned off (i.e., annealed) after its application. Remember Coin B & C are of the same variety and hence from the same counterfeit manufacturing operation. So, Hg and its presence can sometimes be detected or not detected. We can't with 100% confidence say the Hg was better annealed in Coin B's case since if more target areas other than three which were performed on Coin B's surfaces Hg may eventually be detected. Hg's Instrument Detection Level also plays a big part if Hg is detected or not in many cases. Therefore, Coin B may be a mercuric silvered or simply a debased silver with copper counterfeit since the mercuric silver amalgamation wash type technique is the most common silvering technique utilized by counterfeiters of this Kleeberg CCC Family after three decades of Material Analysis research. So, this is the author's opinion based on many numerous XRF assays performed on surface silvered contemporary circulating counterfeit two-reales Kleeberg's in the past 30 years with both XRF Vacuum Analysis and SEM/EDS which also operates in a vacuum chamber and hence able to detect this light element Hg. Hg cannot be detected with XRF analysis in the open atmosphere – only in a XRF vacuum chamber type apparatus. SEM/EDS always operates in a vacuum chamber.

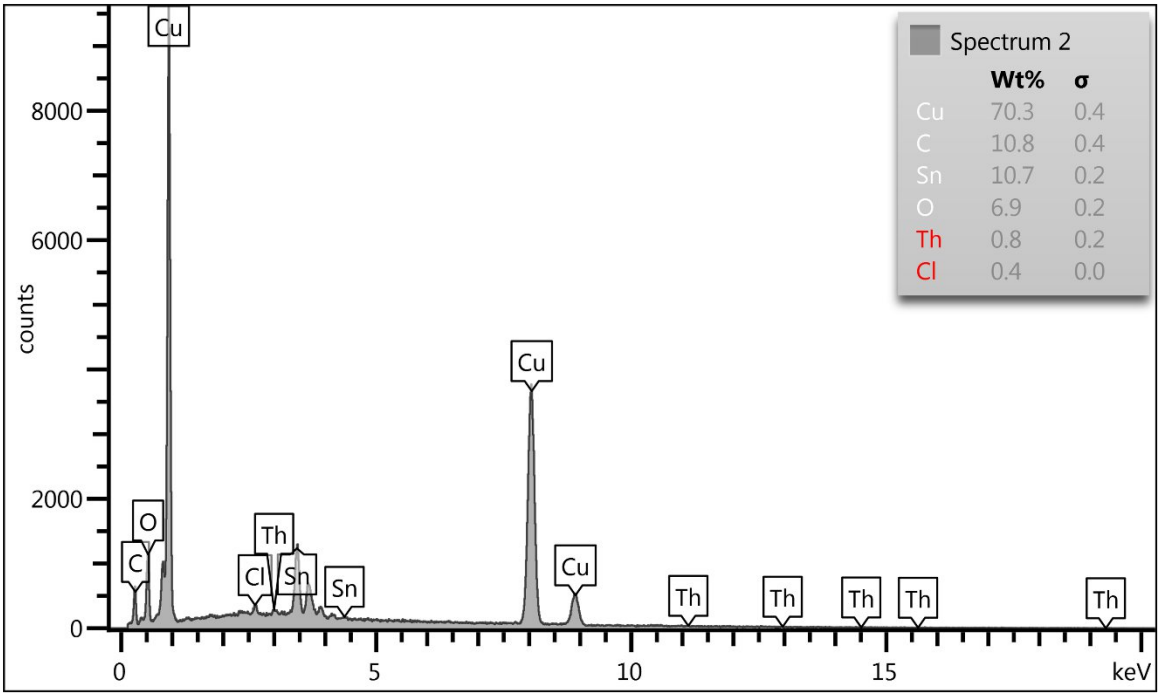


Figure 7-4. **Coin C. Point & ID SEM Micrograph**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 2 Area of Figure 7-2**. **Target Area #1**. An interesting spectrum area of Coin C's surface showing "no silver" which is virtually impossible in a regal 90% Ag/ 10% Cu assay coin. Compare the Point & ID analysis in Phase IV of the regal specimen and compare these results. We see the high copper (Cu) and elevated tin (Sn) in this low tin bronze issue which has been mercuric silvered at the surface which is clear with coin in hand of its silvering. The chloride (Cl) is a surface contaminant, and the thorium (Th) must be some geological ore contaminant carry-over from the manufacturing process of copper or tin in this assay. Thorium is an unusual metal in this assay and was confirmed as not being a false positive by MSU. When we look at copper for example, we know its presence in this coin is as an oxide (i.e., with oxygen) or a carbonate compound (i.e., with both carbon and oxygen). When SEM spectrums are produced the metal is reported independently and the oxide part or oxygen element and carbon or carbonate is also reported independently. This is why within each spectrum we see carbon (C) and oxygen (O) being reported individually. More importantly, this is the first Point & ID spectrum confirming we are not dealing here with a copper CCC host but with a bronze CCC host (Cu/Sn) with tin (Sn) reported at 10.7%.

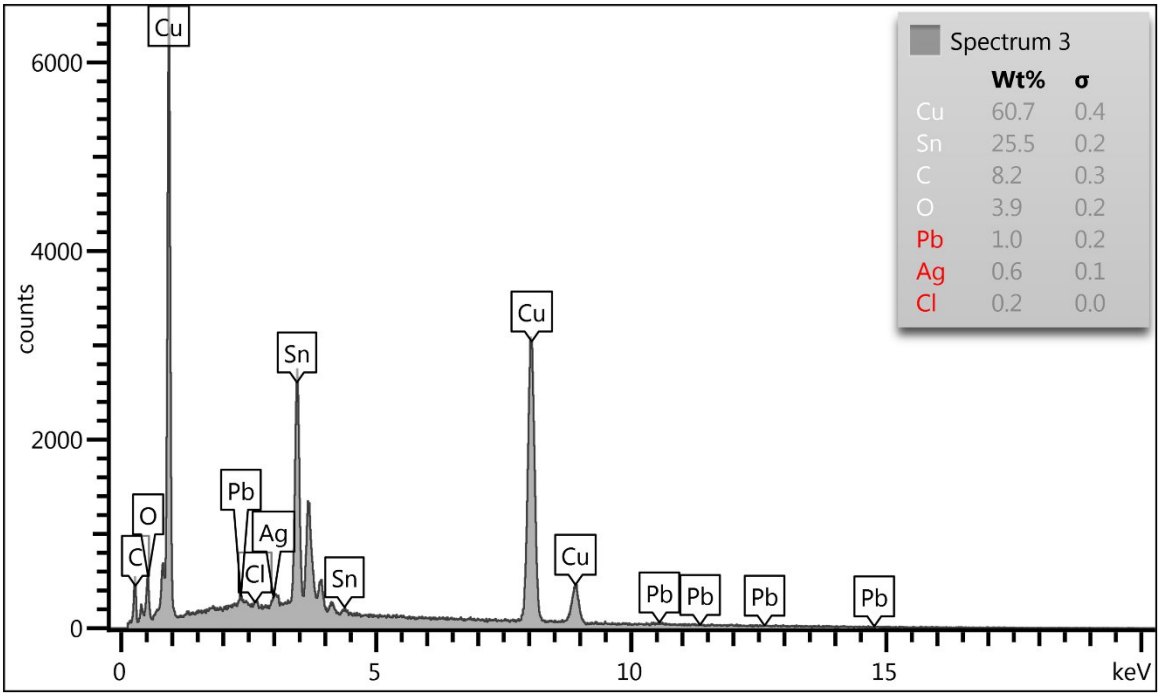


Figure 7-5. **Coin C. Point & ID SEM Micrograph**. **Target Area #1**. Coin C is illustrated in Figure 2. K.19A-L37. Spectrum 3 Area of Figure 7-2. Another very informative spectrum clearly showing to the viewer the perfect mix of metals in this alloy suggesting strongly that Coin C is a silvered surface bronze (Cu/Sn) host alloy coin and clearly Coin C being a contemporary circulating counterfeit two reales Kleeberg. Note the high copper level (60.7%), the high tin (25.5%), trace lead (Pb) probably from the manufacturing process at this low lead level (1.0%), trace silver (Ag) from the surface silver amalgamation application process and chlorine being a surface contaminant here at a trace level of 0.2%. This spectrum alone clearly shows by itself that Coin C is not regal as a 90% Ag issue could never produce a spectrum of this character with tin or copper at these quantitative levels and silver <1%. Compare to Figure 12-4 as a comparison.

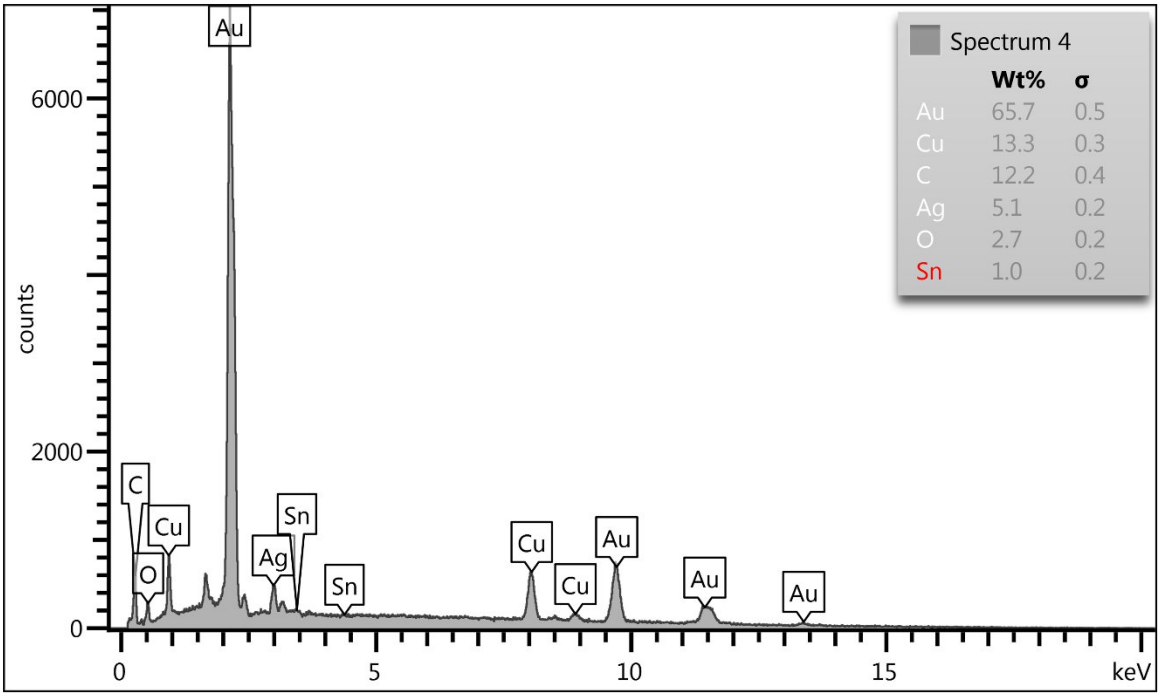
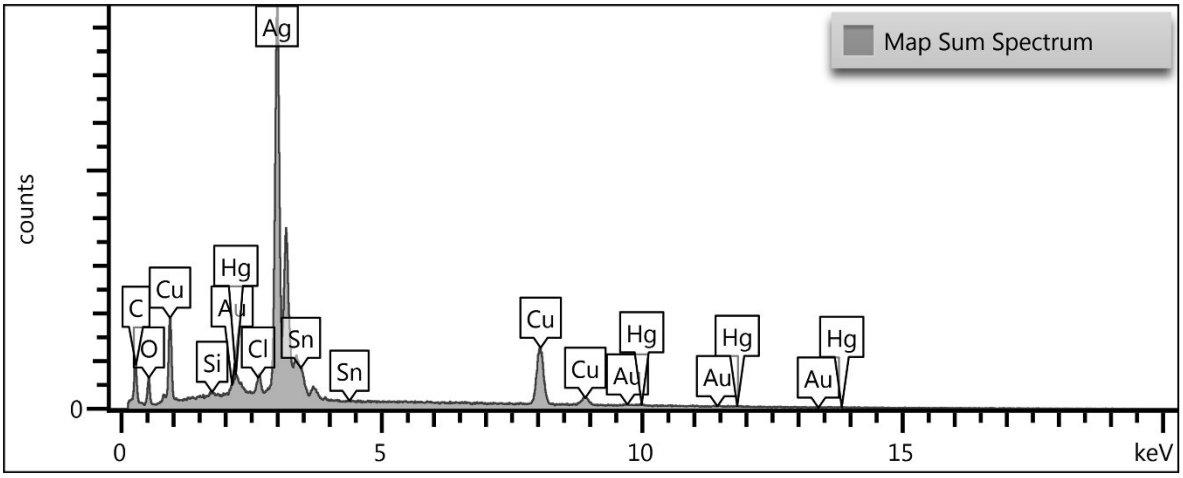
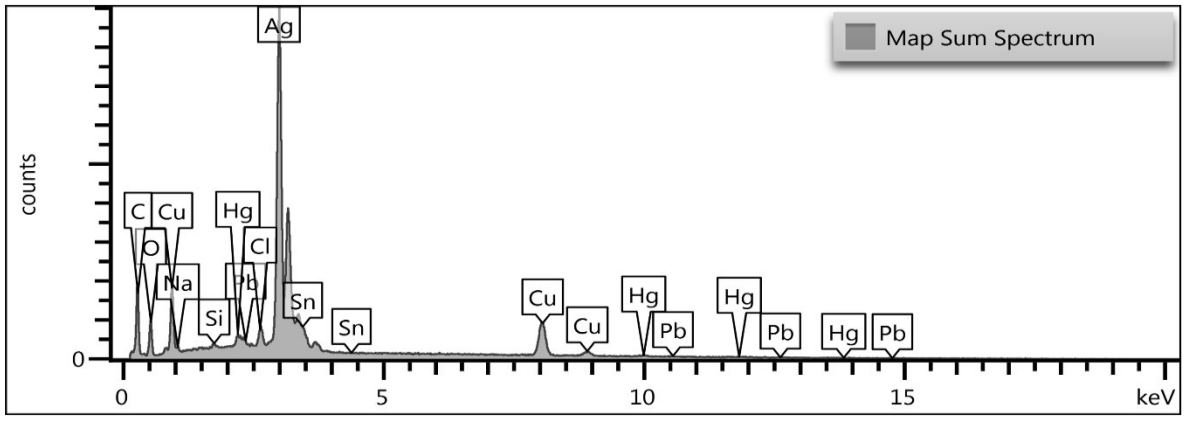


Figure 7-6. **Coin C. Point & ID SEM Micrograph**. **Target Area #1**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 4 Area of Figure 7-2**. A **fascinating** spectrum area where we see a gold (Au) level at 65.7%! This is explained by the fact that during silver mining at times gold is also carried over from the silver ore refining operation. This is mentioned in GNL (2) numerous times when we consider that regal 90% Eight Real specimens have trace gold normally below 1% from the mercury amalgamation process of silver ore refining and that these trace levels of Au are signatures of their regal authenticity period as 18thC/19thC regal Eight Reales. This same type of situation is occurring here. Since we have trace mercuric silvering on the surface, we would expect some trace gold also to be present as part of the surface silvering process. This target shot seems to be almost a perfect “bullseye” shot onto a gold (particle) area and its surrounding region! Along with this high gold reading on the surface we see trace silver from the mercuric silvering process and again copper and tin from the bronze (Cu/Sn) host coin being surfaced silvered with this mercury amalgamation process. An excellent example on how a spectrum area using a Point & ID type analysis can provide at times much more valuable information into a coin assay. It could also be argued that the gold may be some form of contaminant carry-over in the counterfeiting operation. However, this author has detected trace gold in the assay of many silvered or debased silver alloys. Regardless of its origin a surprising spectrum result in this coin area resulting in a gold value detected at an astronomical value of 65.7%!



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.35	0.00346	6.94	0.23	C Vit	Yes	
O	K series	0.36	0.00121	6.69	0.23	SiO2	Yes	
Si	K series	0.01	0.00012	0.15	0.04	SiO2	Yes	
Cl	K series	0.04	0.00033	0.29	0.05	NaCl	Yes	
Cu	K series	2.63	0.02635	20.65	0.25	Cu	Yes	
Ag	L series	6.75	0.06746	57.25	0.36	Ag	Yes	
Sn	L series	0.47	0.00469	4.94	0.18	Sn	Yes	
Au	M series	0.12	0.00116	1.14	0.20	Au	Yes	
Hg	M series	0.22	0.00201	1.95	0.22	HgTe	Yes	
Total:				100.00				

Table 4-1: **Coin C**. Kleeberg 19A-L37. **Map Sum Spectrum (Duplicate Analysis)**. A duplicate analysis was performed in the same general Target Area of Coin C. The analysis clearly shows a mercuric amalgamated silver (Ag & Hg) wash area over a bronze (Cu/Sn) host with trace gold present from the presence of silver. Silicon (Si) and chlorine (Cl) are your typical surface contaminants. With silver registering this high (57.25%) it's no surprise that when Coin C is in hand the silvering over the bronze alloy host coin (Coin C) the silver wash areas are clearly visible with coin in hand with the naked eye and no magnification is needed. This high silver value of 57.25% also helps explain the detection of gold at 1.14% in the assay results.



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.70	0.00700	11.80	0.23	C Vit	Yes	
O	K series	0.56	0.00190	9.99	0.26	SiO2	Yes	
Na	K series	0.03	0.00013	0.37	0.08	Albite	Yes	
Si	K series	0.02	0.00016	0.19	0.04	SiO2	Yes	
Cl	K series	0.07	0.00058	0.47	0.05	NaCl	Yes	
Cu	K series	1.88	0.01876	14.16	0.21	Cu	Yes	
Ag	L series	7.01	0.07010	55.95	0.35	Ag	Yes	
Sn	L series	0.41	0.00408	4.06	0.17	Sn	Yes	
Hg	M series	0.28	0.00251	2.23	0.20	HgTe	Yes	
Pb	M series	0.10	0.00091	0.78	0.21	PbTe	Yes	
Total:				100.00				

Table 4-2: **Coin C.** Kleeberg 19A-L37. **Map Sum Spectrum**. **Target Area #2.** Moving to a different area of the coin's surface in Target Area #2 we are seeing generally the same type of overall alloy. A silvered mercuric (Ag & Hg) wash surface layer over a bronze (Cu/Sn) alloy. The lead (Pb) is a carry-over manufacturing contaminant and sodium (Na), Silicon (Si) & chlorine (Cl) are surface contaminants with sodium (Na) not normally seen as a surface contaminant but probably from soil surface contamination. Again, we are seeing a high level of mercury in this target surface area at 2.23%. Compare this to the regal 1802 Lima Peru Map Sum Spectrum in Figure 12-1.

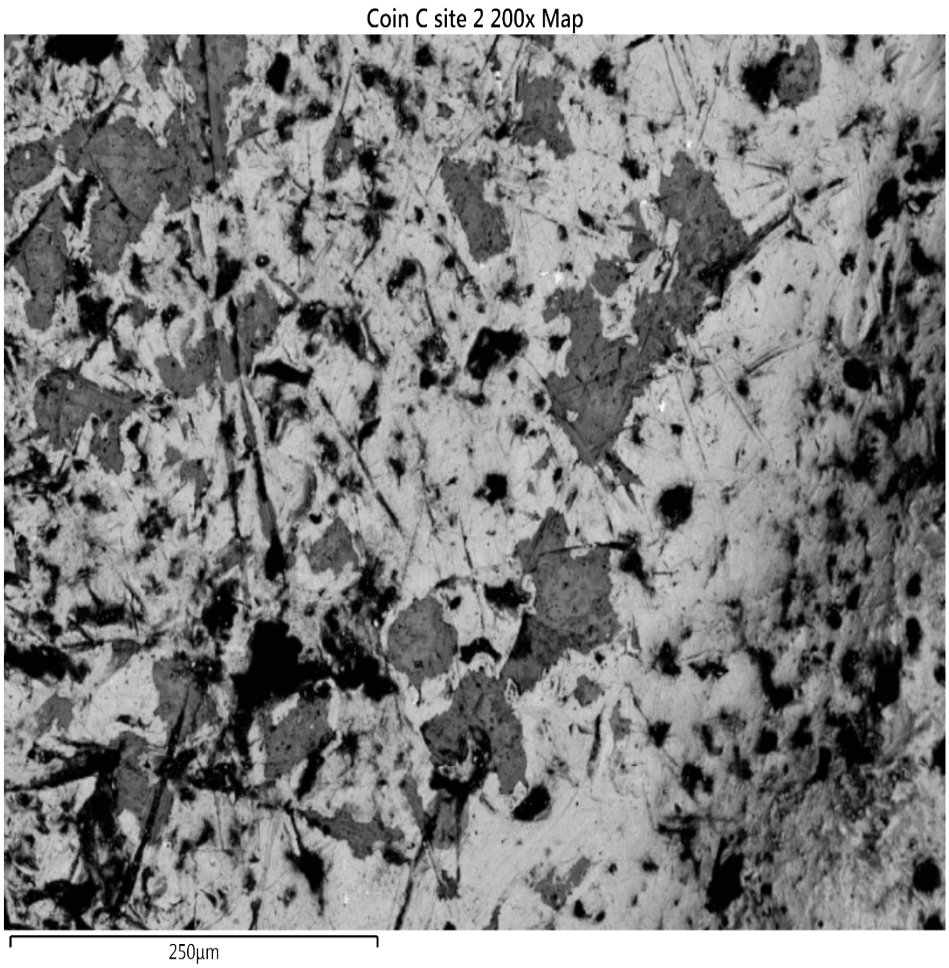


Figure 8-1: **SEM Micrograph of Target Area #2 of #3.** The magnification level here is 200X. The SEM micrograph showing a twin line microstructure and not being of a cast dendritic microstructure as seen in the assay without traces of higher lead with tin and/or zinc normally associated with a cast dendritic metal assay (i.e., such as a bronze leaded alloy). We see linear striations with some jigsaw type patterns. A Point and ID of the different metal or metal alloy areas or different shades of Black & White colorations in this SEM micrograph was performed and appear below in Figures 8-3, 8-4, 8-5 & 8-6. These different spectrum Point & ID areas are circled in Figure 8-2 and were selected by the MSU analyst.

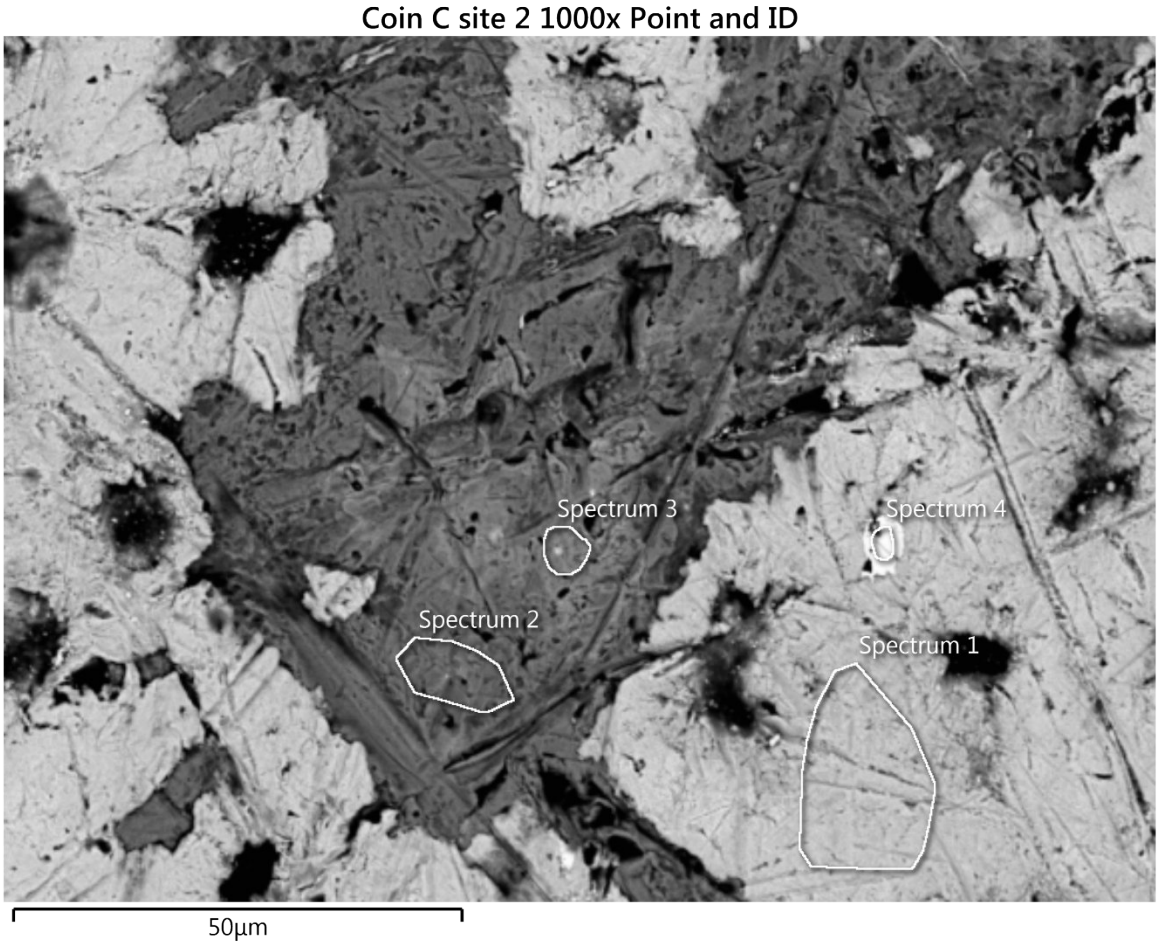


Figure 8-2. **Coin C**. **Point & ID SEM Micrograph**. Coin C is illustrated in Figure 2. K.19A-L37. SEM Micrograph of **Target Area #2**. The magnification level here is 1000X. Spectrums 1, 2, 3 & 4 above were chosen by the MSU analyst which are circled which constitute different shades of black & white imaging representing different metal regions or different metal alloy mixture areas. This Point & ID data in Figures 8-3 through Figures 8-6 clearly show this could not be a 90% silver alloy due to levels of silver and other non-precious metals such as copper being abundant in the alloy mix.

When we view these Map Sum Spectrum for the three Target areas (#1, #2 & #3 with #3 forthcoming), we can see conclusively looking at the metal assays Coin C is something other than a 90% regal silver coin. The author is not going to argue that a simplified XRF surface analysis is easier and more quickly informative to a coin's generic alloy and if its regal or counterfeit using a XRF gun or benchtop XRF device without a vacuum chamber so unable to detect Hg and common surface contaminants such as chlorine (Cl) and sulfur (S). Note the distinctive die struck jigsaw microstructure pattern at this magnification level of 1000X when compared to 200X in Figure 8-1.

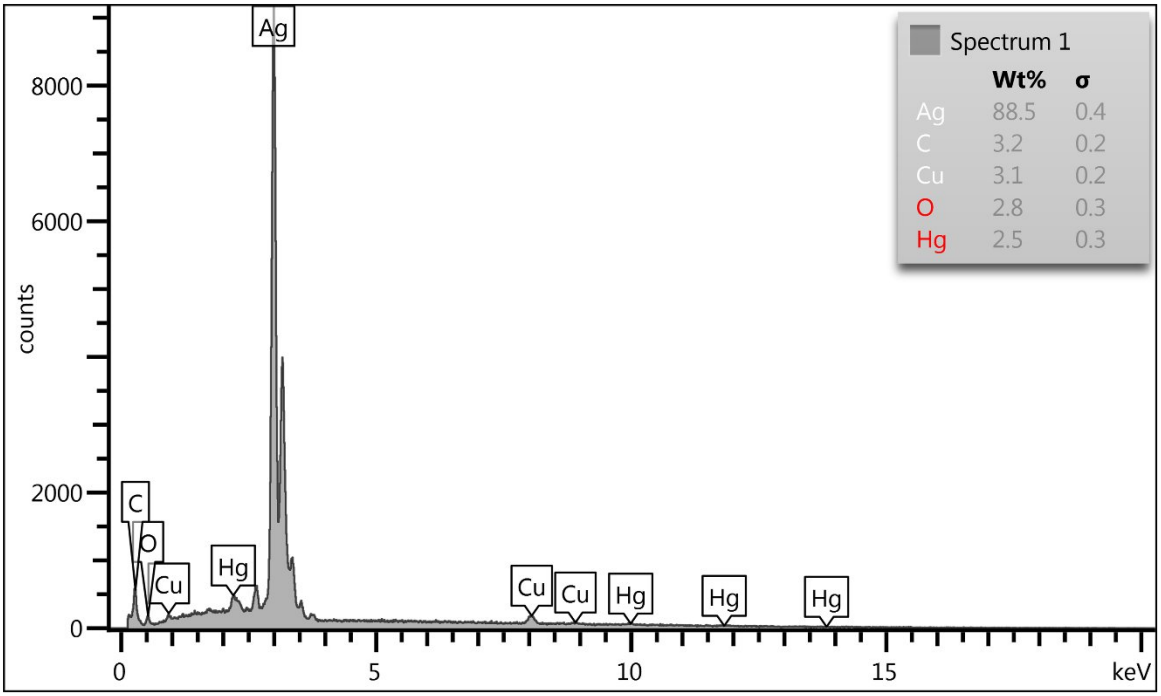


Figure 8-3. **Coin C. Point & ID SEM Micrograph**. **Target Area #2**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 1 Area of Figure 8-2**. This area of the SEM Micrograph as seen in Spectrum assay (top right in photo) illustrates a very high silver area obviously targeting almost exactly a silver particle (or area) as part of the mercuric silver wash. We see low copper in the region along with mercury at a high level (2.5%) confirming the silver is part of a mercuric silver amalgamation wash on Coin C's surface. In this case no surface contaminants are detected such as Si, S & Cl. In this case as the mercury was not properly burned off (i.e., annealed) after its application which possibly was unlike Coin B's situation in which the coin was probably better annealed as no Hg was found in three target area shots or is simply a debased silver with copper host. Remember Coin B & C are of the same variety and hence from the same counterfeit manufacturing operation. So, Hg and its presence can sometimes be detected or not detected. We can't use the idea that Coin B has no Hg and was better annealed with 100% assurance since if more target areas other than three were performed on Coin B's surfaces - Hg may eventually be detected. Hg's Instrument Detection Level also plays a part if its detected or not in many cases. In this case at 0.01% is more than sufficient in finding Hg's presence.

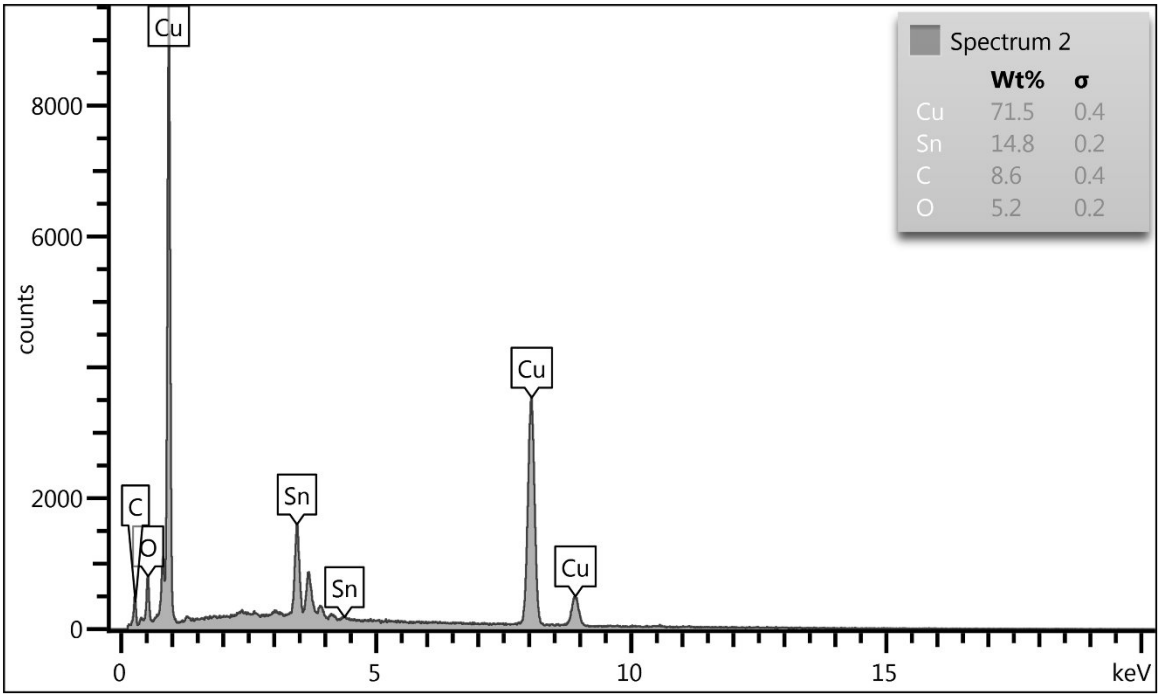


Figure 8-3. **Coin C. Point & ID SEM Micrograph**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 2 Area of Figure 8-2**. In this spectrum area #2 we see primarily a bronze (Cu/Sn) area being detected with no silver being detected at all and again this pretty much demonstrates the metal alloy as not being regal or 90% Ag and clearly a contemporary circulating counterfeit two-reales of an off-metal alloy (i.e., bronze). In this case no mercuric silver wash has been detected in this region and it's strictly reporting based on previous results the basic alloy composition of the host coin being bronze (Cu/Sn). When compared to the regal 1802 coin and reviewing their Point & ID spectrums the possibility this spectrum is from a regal silver issue is essentially nil in its probability when compared to Figures 12-4-6 of the 1802 regal silver issue analyzed in the Phase IV analysis of this study.

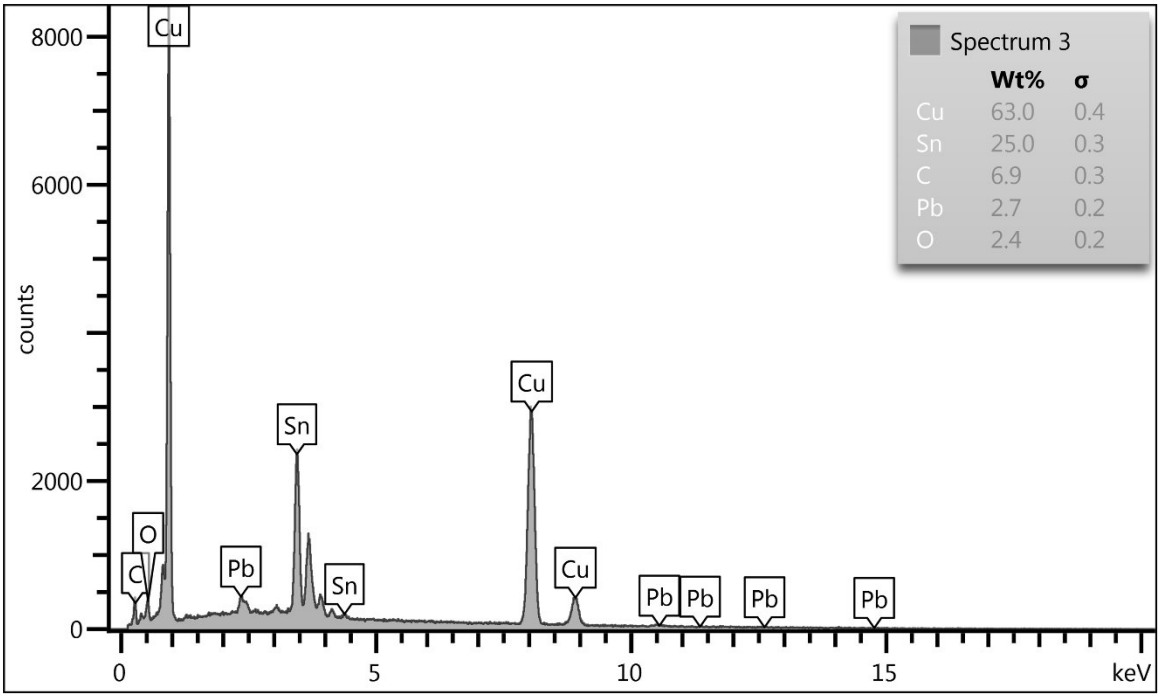
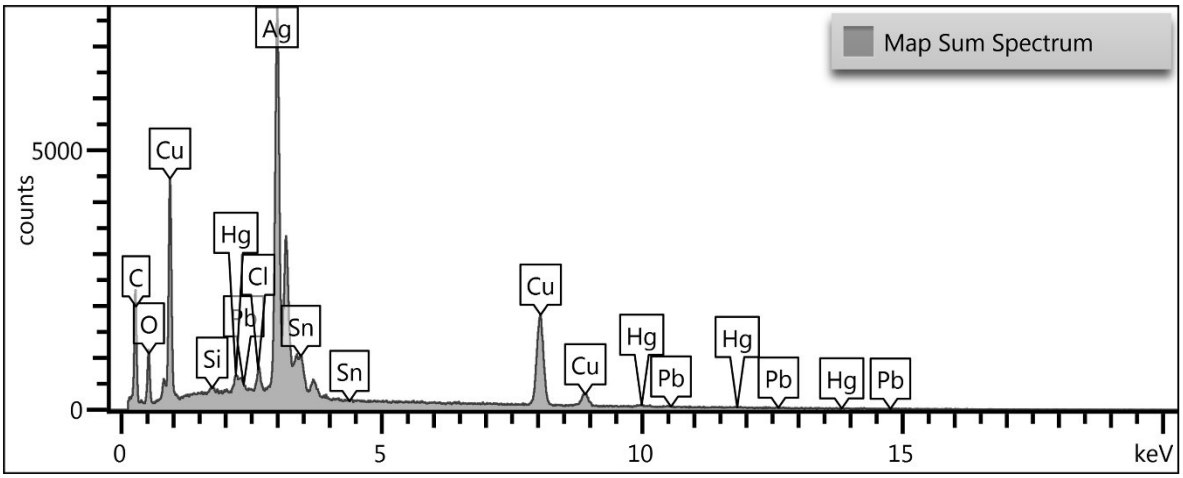


Figure 8-4. Coin C. Point & ID SEM Micrograph. **Target Area #2**. Coin C is illustrated in Figure 2. K.19A-L37**. Spectrum 3 Area** of Figure 8-2. In this spectrum area of Target #2 we see primarily a bronze (Cu/Sn) area being detected with no silver being detected at all and again this pretty much demonstrates the metal alloy as not being regal or 90% Ag and is a contemporary circulating counterfeit two-reales of an off-metal alloy (i.e., bronze). The high trace lead (Pb) at 2.7% probably from a manufacturing carry-over scenario in the opinion of the author as the microstructure profile is twin line, the coin is struck in appearance and the Pb value is normally higher in cast planchets if present or intentionally added and not ore related. Coin C's planchet when examined is neither of a polished rim or evidence of having rim burr removal resulting from a casting mold operation, the lettering is not dumpy but sharp, crisp and bold and the coin has a long coin ring. An interesting spectrum possibly suggesting cast by itself but with data from other target areas, multiple Point & ID spectrums along with the SEM micrograph microstructure examinations the overall physical in-hand appearance of the coin is simply not a cast specimen. This is the main reason we will be looking at George II casts and view their metal assays and their SEM Micrograph Microstructures with the same type of three-tier SEM/EDS analysis. This will be performed during the Phase III results in this paper so the reader has comparisons of what a cast and struck coins will show in their SEM micrographs.



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
C	K series	0.83	0.00835	15.01	0.26	C Vit	Yes	
O	K series	0.65	0.00218	8.94	0.22	SiO2	Yes	
Si	K series	0.02	0.00014	0.15	0.04	SiO2	Yes	
Cl	K series	0.06	0.00050	0.36	0.04	NaCl	Yes	
Cu	K series	3.79	0.03785	24.97	0.24	Cu	Yes	
Ag	L series	6.01	0.06010	42.50	0.29	Ag	Yes	
Sn	L series	0.63	0.00628	5.24	0.15	Sn	Yes	
Hg	M series	0.29	0.00266	2.13	0.19	HgTe	Yes	
Pb	M series	0.10	0.00090	0.69	0.20	PbTe	Yes	
Total:				100.00				

Table 2-3: **Coin C.** Kleeberg 19A-L37. **Map Sum Spectrum**. **Target Area #3.** Moving to the final area of the coin's surface is Target Area #3 here and we are seeing generally the same type of overall alloy as in the previous two target areas. A silvered mercuric (Ag & Hg) wash surface layer over a bronze (Cu/Sn) host alloy. The lead is a carry-over manufacturing contaminant and silicon (Si) & chlorine (Cl) are surface contaminants. Again, we are seeing a very high level of mercury on the surface with a quantitative level of 2.13%.

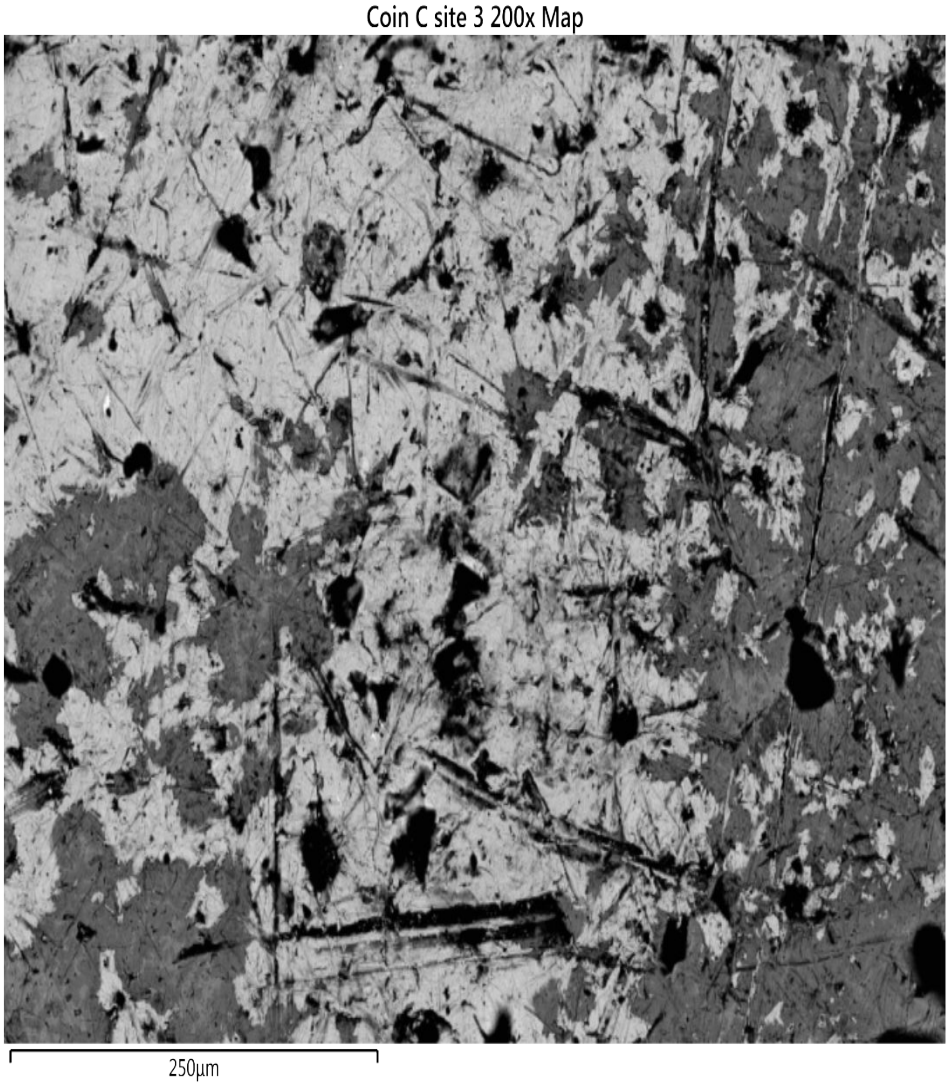


Figure 9-1: **SEM Micrograph of Target Area #3.** The magnification level here is 200X. The SEM micrograph shows a twin line microstructure (straight line striations and a jigsaw like pattern) and not being of a cast dendritic microstructure as seen in the assay without traces of higher lead normally associated with a cast dendritic metal assay (i.e., such as a bronze leaded alloy). A Point and ID of the different metal areas or different shades of Black & White colorations in this SEM micrograph was performed and appear below in Figures 9-3, 9-4, 9-5 & 9-6. The spectrum areas identified by the MSU analyst are circled and seen in the next figure Figures 9-2.

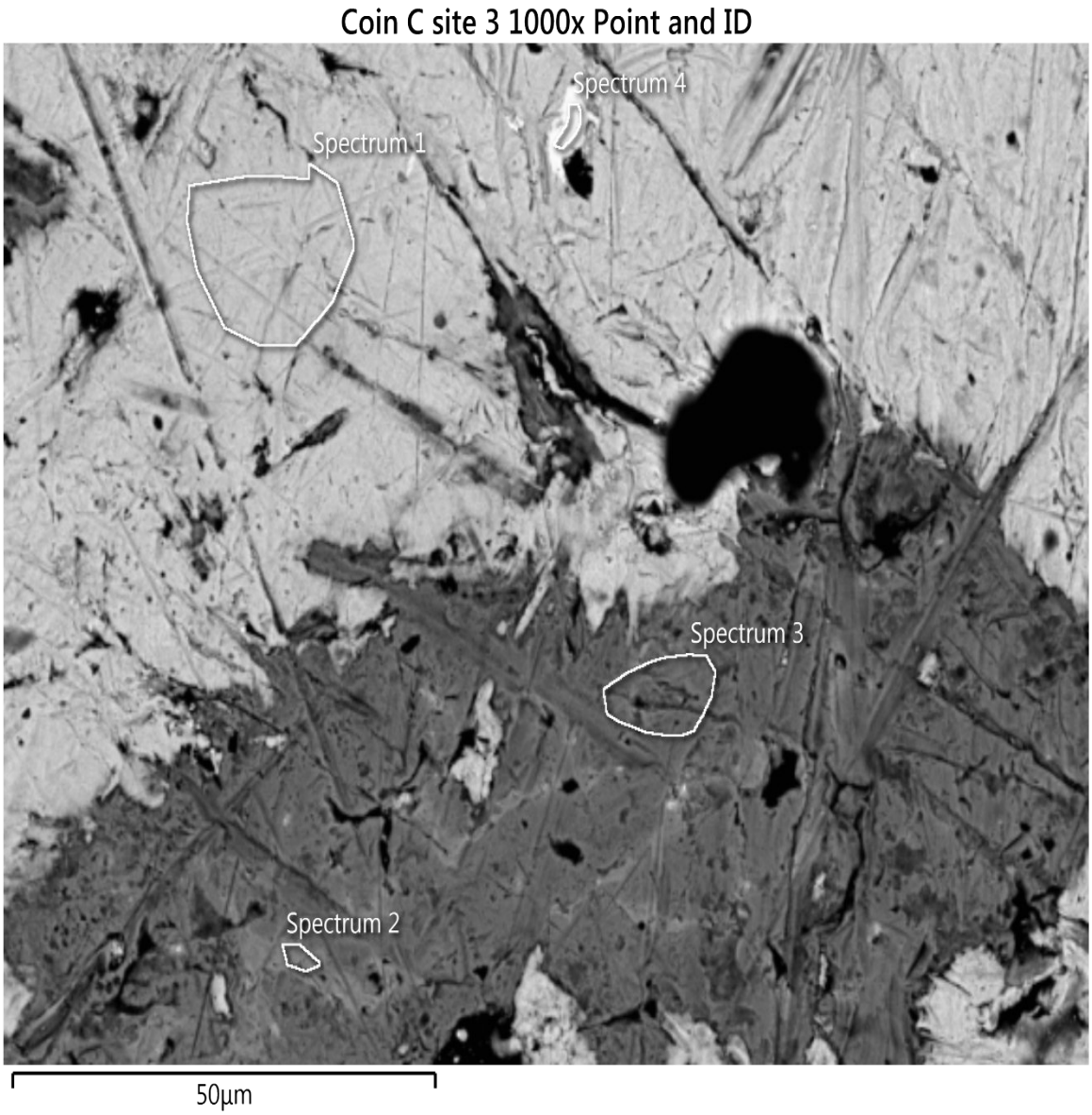


Figure 9-2. **Coin C**. **Point & ID SEM Micrograph**. Coin C is illustrated in Figure 2. K.19A-L37. SEM Micrograph of **Target Area #3.** The magnification level here is 1000X. Spectrums 1, 2, 3 & 4 above were chosen from these different areas which are circled which constitute different shades of black & white imaging representing different metal regions or different metal alloy mixture areas. This Point & ID clearly shows this could not be a 90% silver alloy due to levels of silver and other non-precious metals such as copper with its high percentages in the alloy mix. Some areas indicating here at a 1000X level of a jigsaw pattern but not as clear as the other two target areas.

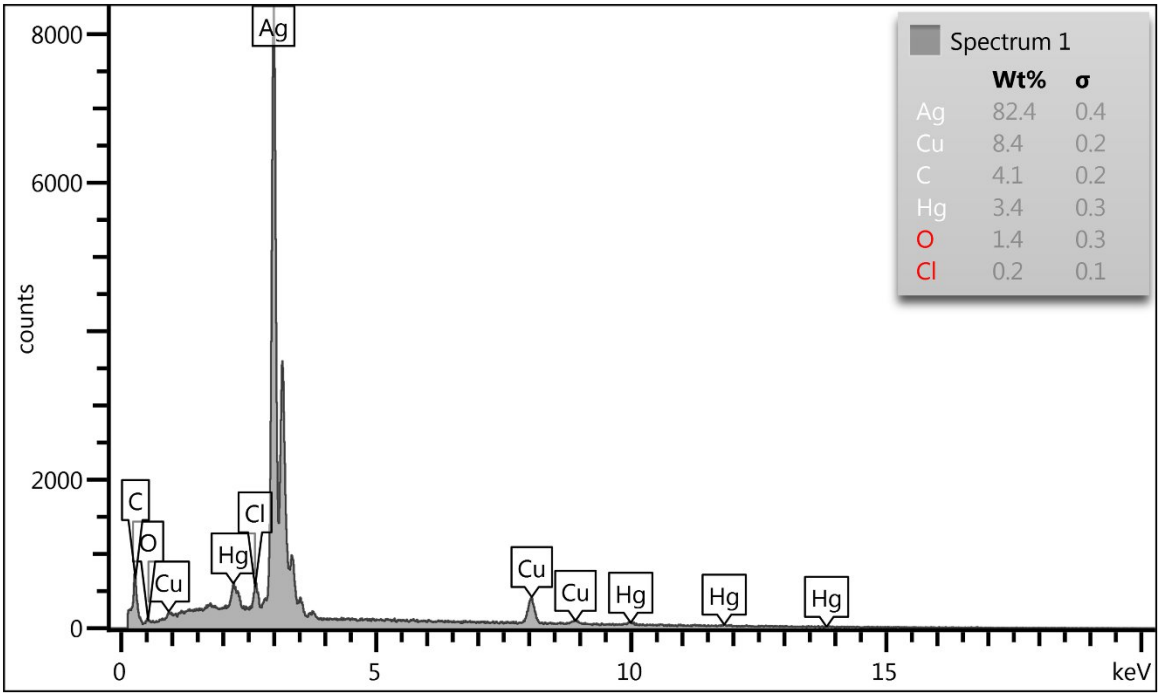


Figure 9-3. **Coin C. Point & ID SEM Micrograph**. **Target Area #3**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 1 Area of Figure 9-2**. This target point illustrates a target area of a silver particle (area) or silver area of the silver wash. In this area we see Hg at 3.4% the vehicle used to spread the silver paste over the surface of Coin C. This value being very high. Chlorine is present as a surface contaminant and not part of the alloy mix. In previous target spectrums although not very many we have seen elevated silver but nothing near the 90% Ag regal level. The only possible explanation for a mercury level this high on Coin C's surface is if it was applied after Coin C was created and has nothing to do at all with the silver ore amalgamation process of silver ore mining and trace mercury. We see this with regal 90% Ag Eight Reales where the Hg level is generally <1% and rarely exceeds a value between 1-2%. In Coin C's case here this Hg was manually applied to powdered silver and then applied to the coin's surface as a paste. It's then annealed creating the silvered surfaces collectors normally see for these types of Spanish/American CCC's of this denomination as well as other denominations such as ½R, 1R, 4R & 8R's which are silvered CCC's.

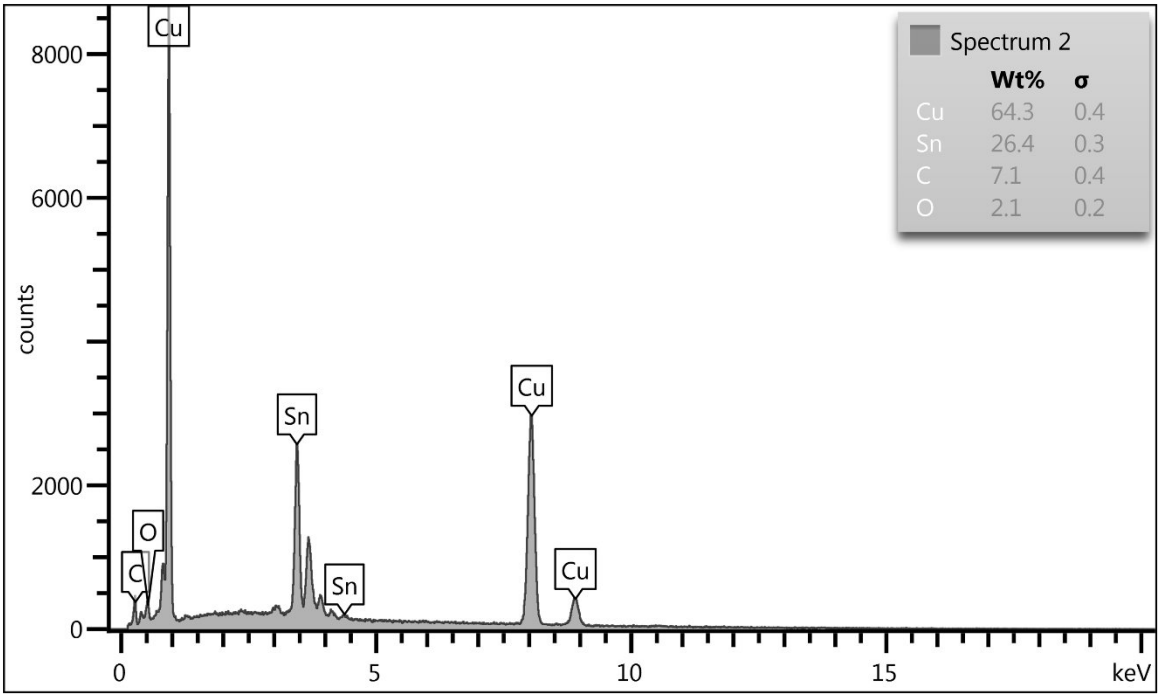


Figure 9-4. **Coin C. Point & ID SEM Micrograph**. **Target Area #3**. Coin C is illustrated in Figure 2. K.19A-L37. Spectrum 2 Area of Figure 9-2. The most informative spectrum in Target Area #3 in the author's opinion really shows the true alloy mix of this off-metal contemporary circulating counterfeit regal looking two Reales. Showing a bronze alloy (Cu/Sn) mix with no traceable silver to a 0.1% Instrument Detection Level. When compared to Figure 9-3 it should be clear in Coin C's case that one area is rich in silver and another adjacent area is totally void of silver on the surface. An impossibility in a 90% Ag alloy mix from my experience. We shall see this in the forthcoming Phase IV section of the SEM/EDS analysis of the 1802 Lima Peru regal standard analysis more clearly when compared to Figures 12-4-6 the Point & ID analysis of the 1802 regal silver specimen.

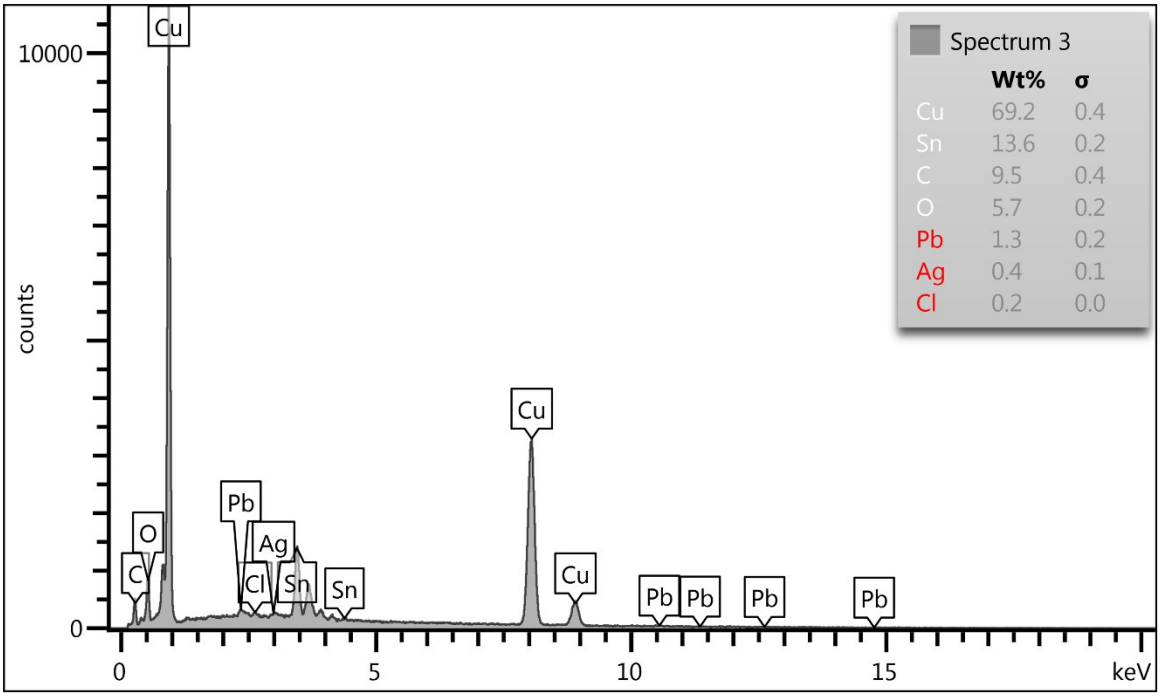


Figure 9-5. **Coin C. Point & ID SEM Micrograph**. **Target Area #3**. Coin C is illustrated in Figure 2. K.19A-L37. Spectrum 3 Area of Figure 9-2. In this shaded area (Spectrum 3 Area) we find bronze (Cu/Sn) with traces of lead as a probable ore manufacturing contaminant with trace silver (0.4%) and the surface airborne air contaminant chlorine (Cl) also on the surface. The lead does not seem to be coming from the cupellation or manufacturing process of silver ore manufacturing. The reason is since its appearance is not associated with a high silver presence where here we see 1.3% lead (Pb) and only 0.4% silver (Ag). This lead does not seem to be intentionally added and is an outside contaminant from an unknown source. The microstructure of Coin C being struck also provides strong evidence that lead (Pb) in this assay was not intentionally added into the alloy mix by the counterfeiter as is normally done to reduce the melting point of the liquid metal being added to cast mold operations.

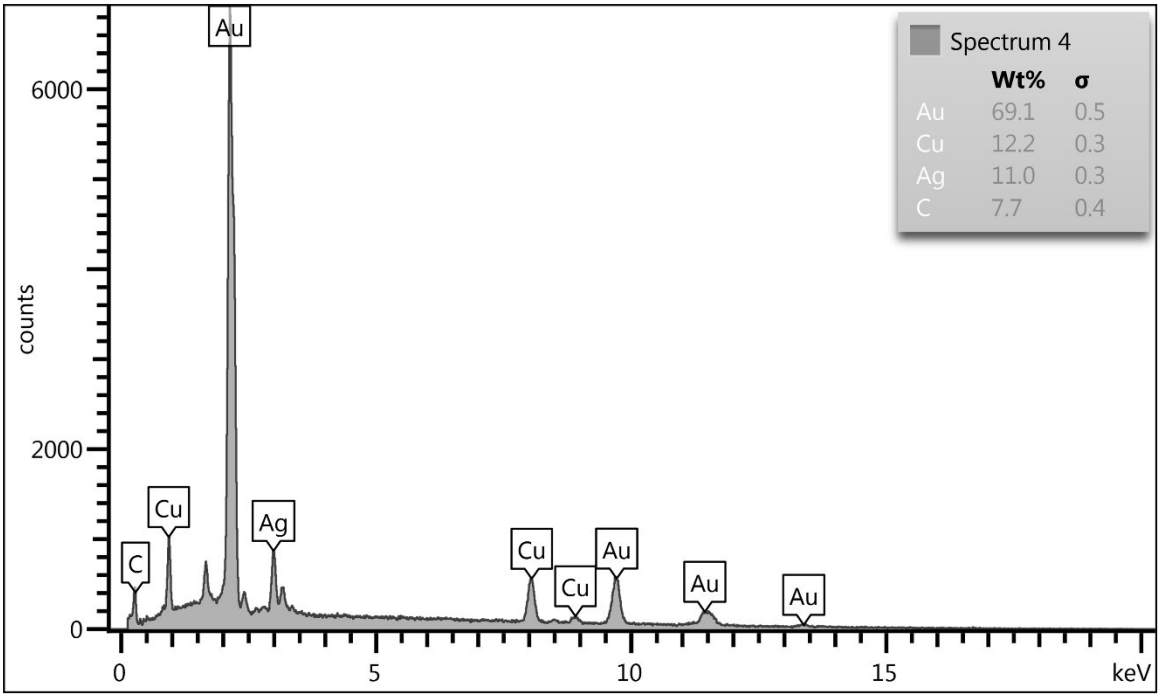


Figure 9-6. **Coin C. Point & ID SEM Micrograph**. **Target Area #3**. Coin C is illustrated in Figure 2. K.19A-L37. **Spectrum 4 Area of Figure 9-2**. A spectrum result we have seen before whereupon when there is silver present, we can also expect gold in the analysis. The target area here we find gold particles (area) as well as silver particles from the surface silver amalgamation process. With this type of pinpoint target analysis and high magnification we can detect both silver and gold trace residues on the surface. A value this high with XRF analysis is not expected for gold since its target area is much wider. Interesting indeed with a gold value nearly “seven” times the silver value with copper at 12.2%.

Coin C Mass Sum Spectrum Analysis Summation

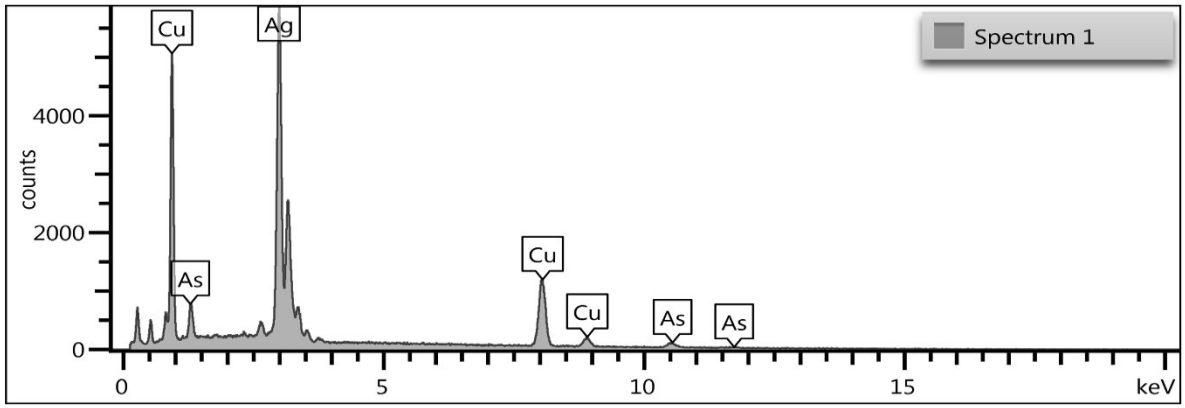
From the Map Sum Spectrums and Point & ID spectrums we seem to have a silvered surface bronze (Cu/Sn) host coin with a mercury amalgamation silver type surface application at Coin C’s surface. The SEM micrograph microstructure confirms it’s a struck example and not cast in a mold even though it’s a low leaded bronze alloy. Its surface features such as its motifs and its metrology and in-hand appearance also confirm its die struck manufacture. The next section will review Coin B & C with polished surfaces which will reduce or eliminate the surface contaminant levels and exemplify the metal assay of host coins with currently Coin B being a high copper/trace zinc alloy or debased silver alloy with copper and Coin C being a mercuric silvered bronze (Cu/Sn) alloy. These conclusions for both Coin B & C will also be clarified even more after the regal 1802 Lima Peru specimen goes through a three-tier SEM/EDS full profile analysis forthcoming in this paper in Phase IV.

Phase II Analysis: Single Target Areas of Coins B & C within Hand Polished Areas

Purpose

As described earlier an attempt to polish off the corrosion layer of the two principal coins for analysis K.19A-L37 specimens B & C was performed by the MSU Material Analysis Laboratory using ordinary fine grit sandpaper along the rim area of the coins (i.e., the so-called third side). This small area along the rim area (i.e., third side of the coin) was chosen to reduce somewhat the visual damage to the coin as these are collectible artifacts. It's common knowledge that the central core or inner area of the coin is much more representative of the coin's original makeup than the surface. For cost considerations the author felt that one target shot was all that was needed to get a general idea of the coin's original alloy.

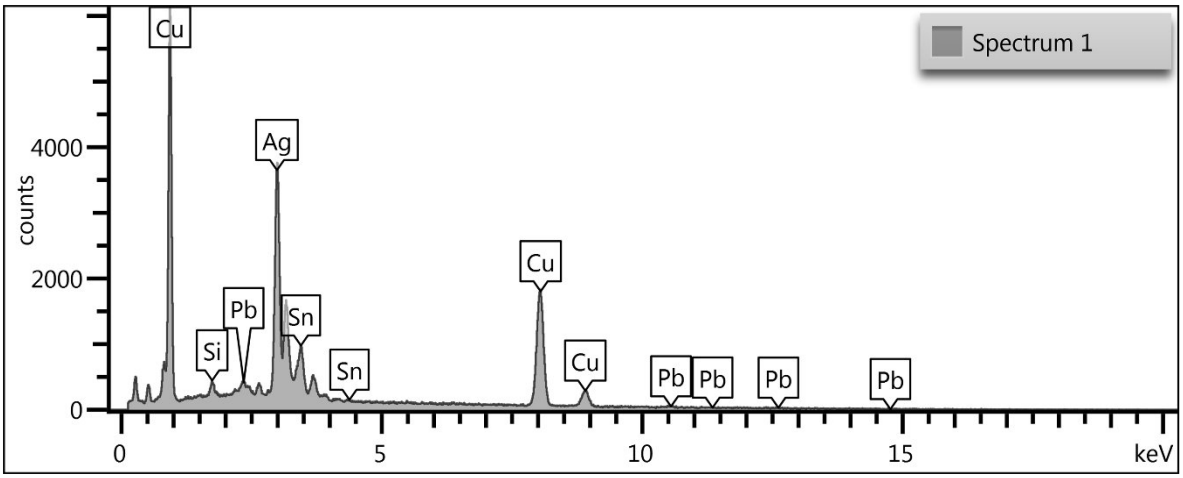
SEM/EDS Results of Coin B Polished Results



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Cu	K series	4.88	0.04883	30.26	0.31	Cu	Yes	
As	L series	0.74	0.00393	6.73	0.24	InAs	Yes	
Ag	L series	9.08	0.09085	63.01	0.34	Ag	Yes	
Total:				100.00				

Figure 10-1. **Coin B. Polished Area**. When in Phase I we assumed it was surface silvering, but we could not detect mercury (Hg). We also did not see silver in some Point & ID's but due to the magnification level these areas were just picking up copper (Cu). The Map Sum Spectrum suggests a debased silver counterfeit with copper. But the area has been polished so Mercury (Hg) if present would likely be polished away. The Arsenic (As), as described before in the opinion of the author, comes from a poorly annealed copper source. Note the absence of surface contaminants after the surface has been polished. Note the high level of copper (30.26%) and low level of silver (63.01%) to a regal composition. It could be considered unusual to surface silver a host coin with 63.01% Ag.

SEM/EDS Results of Coin C Polished Results



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Si	K series	0.09	0.00072	0.86	0.07	SiO2	Yes	
Cu	K series	7.49	0.07485	45.70	0.35	Cu	Yes	
Ag	L series	5.71	0.05709	40.00	0.34	Ag	Yes	
Sn	L series	1.39	0.01395	11.20	0.25	Sn	Yes	
Pb	M series	0.30	0.00277	2.25	0.30	PbTe	Yes	
Total:				100.00				

Figure 10-2. **Coin C. Polished Area**. These results confirm that Coin C's base alloy is indeed bronze (Cu/Sn). Surprisingly the silver value here is at 40% which makes this more accurately a counterfeit host coin of a silver alloy debased with bronze then silvered at the surface with a mercuric silver amalgamation wash as the final process step by the counterfeiter. Quite a complex contemporary circulating counterfeit considering this is also regal in appearance. We are forced now to call this a debased silver issue with bronze since the almost universal appearance of mercury at levels >1% on the surface found in the unpolished results can only come from a man-induced operation applying Hg at these high levels. A fascinating specimen and when incorporating both XRF (authors results) with an in-depth multi-target SEM/EDS surface analysis of the original unpolished surface area the result here is quite eye-opening. Why was this alloy mercuric silvered? An unusual piece. A silver alloy debased with bronze (Cu/Sn) then mercuric silvered. Silver apparently very high in the counterfeit host coin at 40% in this single target polished Coin C area.

SEM Micrograph Microstructure Coin C Polished Area (Magnification 200X)

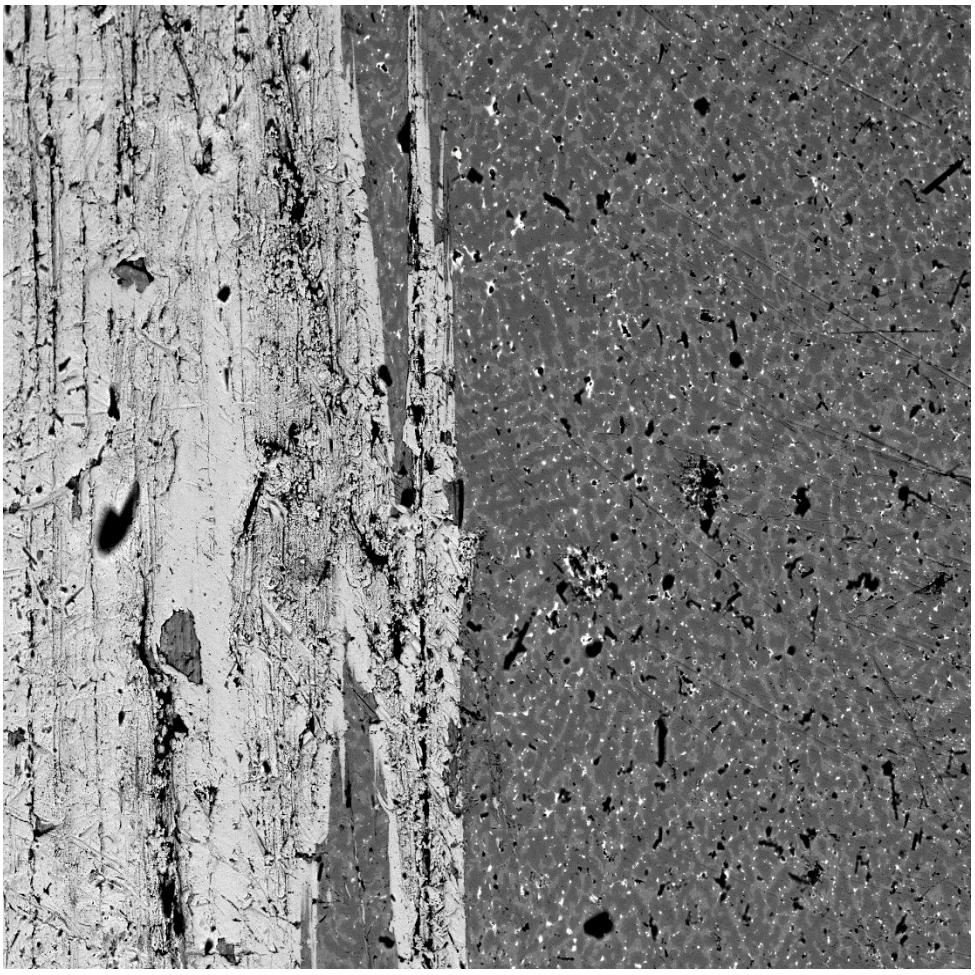


Figure 10-3. SEM Micrograph Microstructure image (200X Magnification Level) of Coin C's polished surface not indicating any signs of a dendritic cast microstructure with linear striations and a jigsaw type pattern particularly seen the right dark area. Due to cost limitations the author did not feel a Point & ID was needed here but this seems to show the interface area between a silver (left white area) and copper/tin area (right dark area). I suspect the small black areas may be areas high in Arsenic (As) due primarily to the high copper in the assay.

SEM Micrograph Microstructure Coin B Polished Area (Magnification 200X)

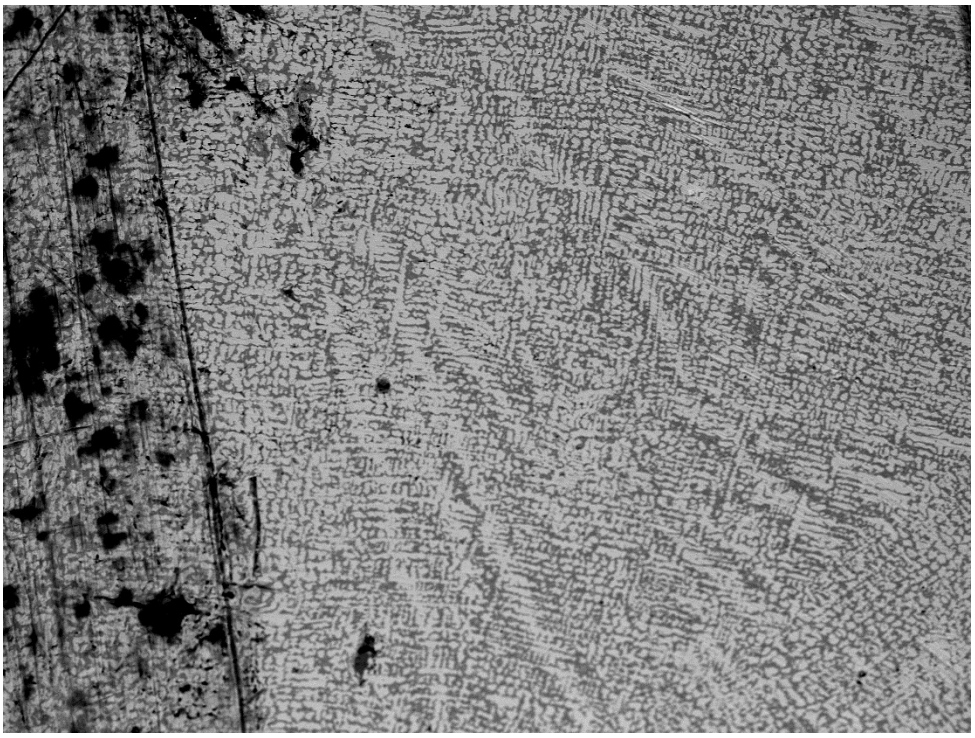


Figure 10-4. SEM Micrograph Microstructure of Coin B at a magnification of 200X indicating a struck twin line microstructure. Due to cost limitations no Point & ID was performed since the main goal of these polished area SEM Micrograph singular target shots was to determine if their microstructure was either cast dendritic or twin line struck. The author suspects the dark areas are Arsenic (As). In a Point & ID analysis if we raise the magnification level here to 1000X the different shaded black and white photograph regions are “more distinct” in their selection to perform a Point & ID analysis. We see this in the Phase I results where we chose to do most Point & ID MSU circled in the photomicrograph spectrum area selections at this magnification level of 1000X. Again, the Map Sum Spectra seen in Figure 10-1 has confirmed that Coin B is most likely a debased silver with copper contemporary circulating counterfeit.

Conclusion

Coin B is either a debased silver issue with copper or is a mercuric silver copper host with no Hg able to be detected after targeting three target areas. Coin C is a confirmed mercuric surface silvered issue upon a silver alloy host coin which is debased with both copper and tin (i.e., bronze mixture).

Phase III Analysis: SEM Micrograph Microstructures and Map Sum Spectrums of Polished Cast George II Contemporary Circulating Counterfeit Halfpence and Struck George III Contemporary Circulating Halfpence

Specimen #1 1730 English Cast George II Contemporary Circulating Counterfeit

Figure 11-1 (a) Obverse (top photo) and reverse images of the 1730 English Cast CCC Halfpence

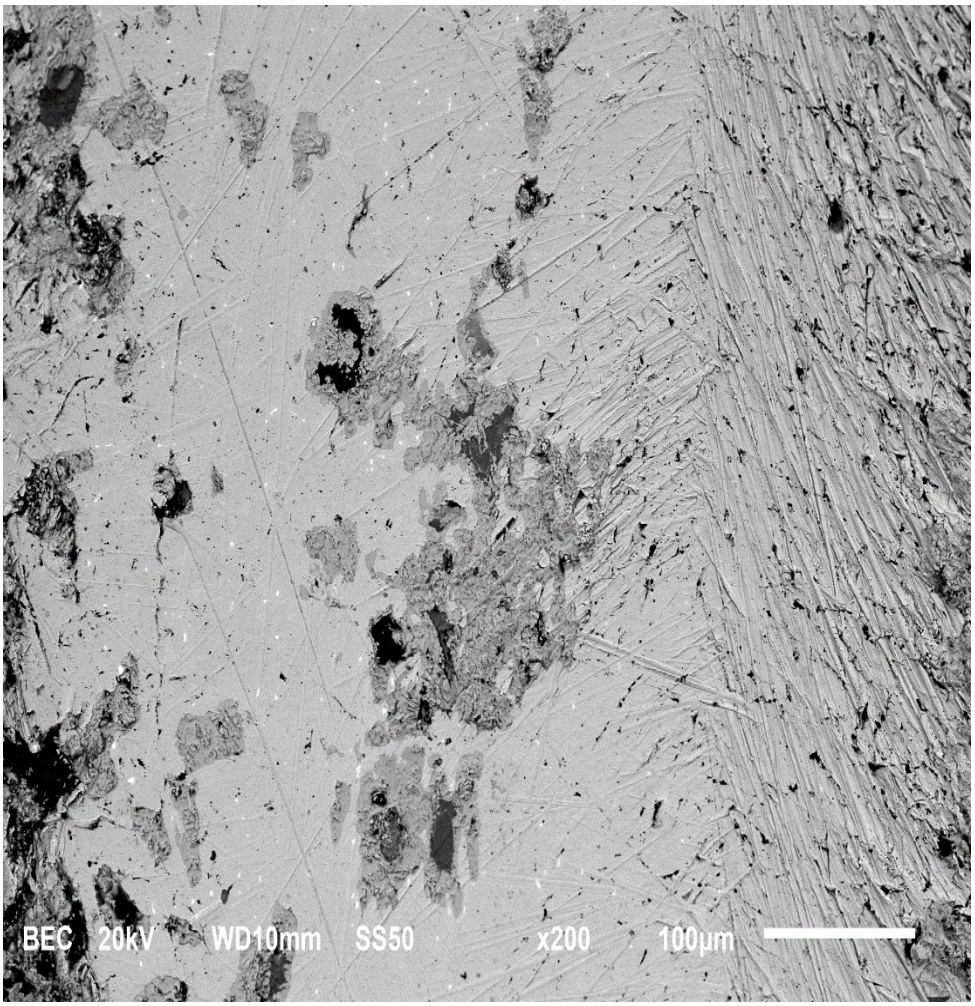
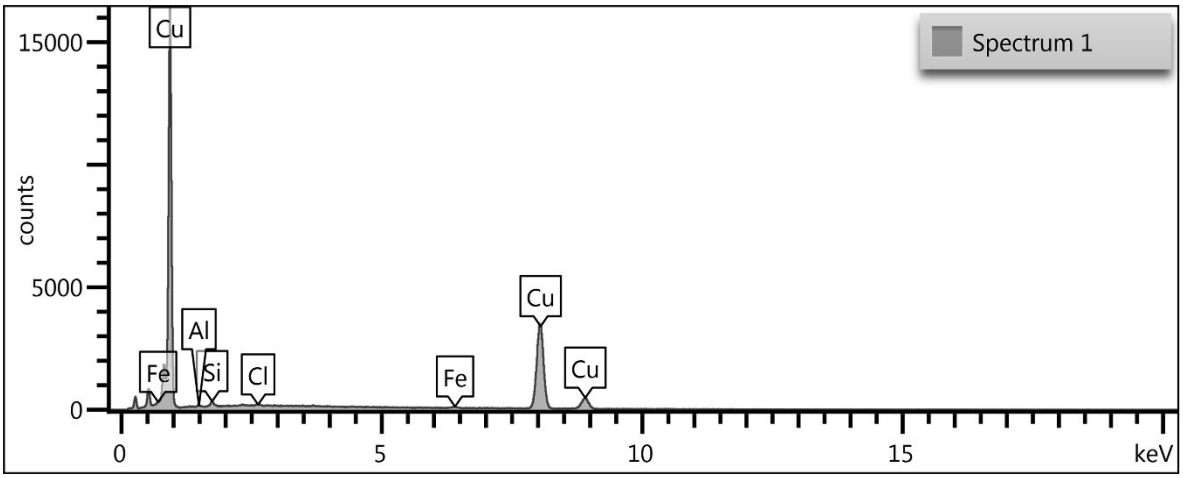


Figure 11-1(b) SEM Micrograph Microstructure of 1730 English Cast George II Contemporary Circulating Counterfeit indicating a dendritic cast microstructure. An interesting Map Sum Spectra of the assay in Figure 11-1 (c) indicating no tin (Sn), Lead (Pb) or Zinc (Zn) in the metal alloy mix. This is sort of contradictory to modern numismatic information that at times but rarely George II casts can be made up of just a high copper (Cu) assay. Lead is normally added to lower the boiling point of copper since a Cu/Pb mixture is easier to cast in a casting mold as lead drops the melting point significantly. Not in this case. It can be argued that more sampling target points are necessary to verify the absence of lead in this cast contemporary circulating counterfeit. Compare the similar nebulae pattern to R.A. Scott's dendritic cast microstructure example seen in Figure 11-6. This microstructure is not of a die struck coin with no real striata or jigsaw pattern microstructure observed.



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Al	K series	0.02	0.00016	0.40	0.09	Al2O3	Yes	
Si	K series	0.08	0.00061	1.04	0.08	SiO2	Yes	
Cl	K series	0.03	0.00029	0.28	0.06	NaCl	Yes	
Fe	K series	0.11	0.00113	0.63	0.08	Fe	Yes	
Cu	K series	13.92	0.13923	97.65	0.16	Cu	Yes	
Total:				100.00				

Figure 11-1 (c) Map Sum Spectra of 1730 English Cast George II Contemporary Circulating Counterfeit from a Polished Area. A high copper cast specimen. Interesting analysis of a high copper assay with no tin, zinc or lead so the idea of a cast George II must be always a leaded bronze (Cu/Sn), leaded bronze/brass (Cu/Sn/Zn) or of a brass (Cu/Zn) mixture may possibly not be always correct as per Mossman/Smith (23). See also the Mossman/Smith Empirical formula definition in the glossary of terms. More target points may be in order to verify the absence of lead. The Iron (Fe) probably at this level (<1%) is a mining ore contaminant carry-over. Even after the coin's surface was polished silicon (Si) and Chlorine (Cl) remain as common surface environmental contaminants. Aluminum (Al) may have been picked up from the polishing event and is also not considered part of the coin's alloy.

Specimen #2 1739 English Cast George II Contemporary Circulating Counterfeit Ex. Jesse Holzer Collection

Figure 11-2 (a) Obverse (top photo) and reverse images of the 1739 English Cast CCC Halfpence

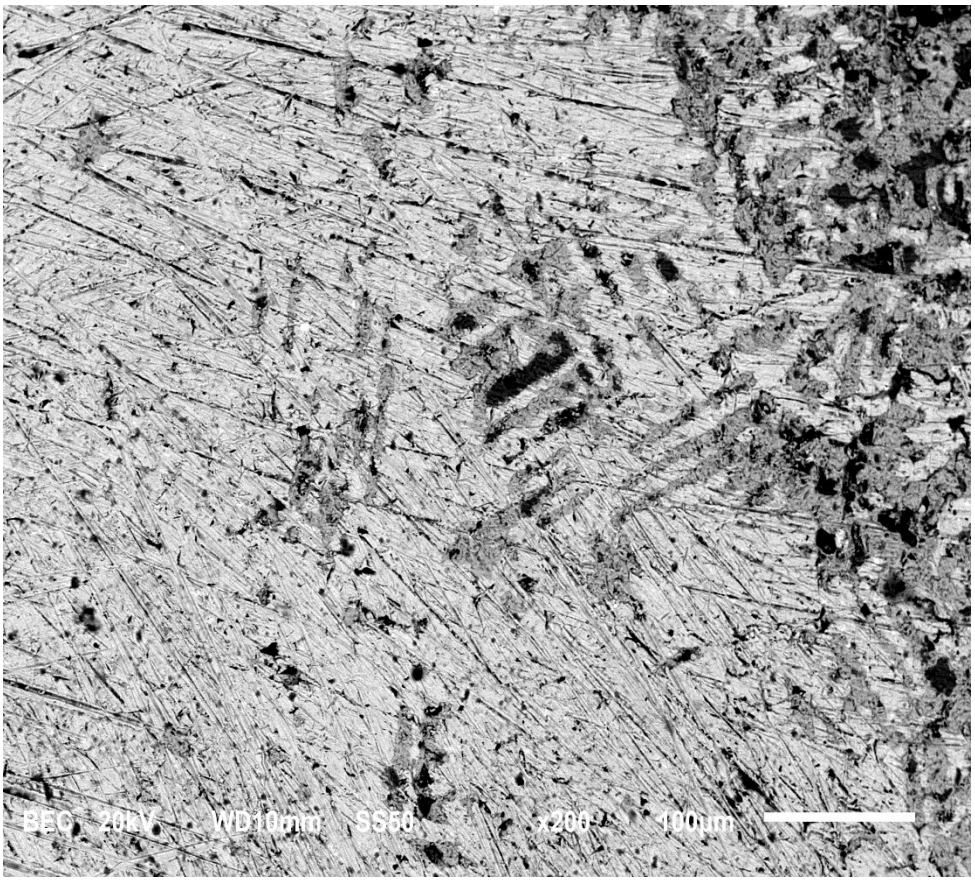
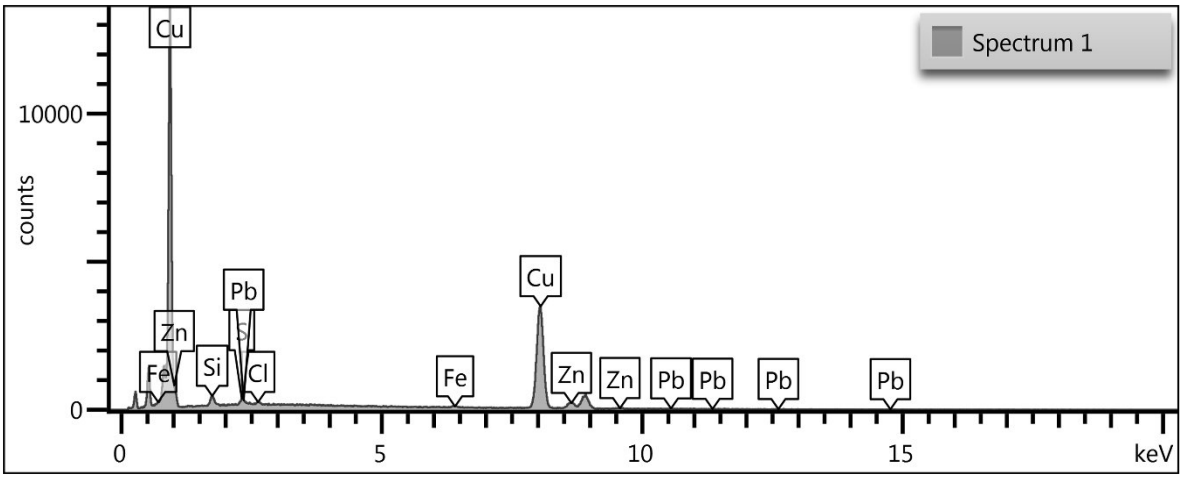


Figure 11-2 (b) SEM Micrograph Microstructure of 1739 English Cast George II Contemporary Circulating Counterfeit indicating a dendritic cast microstructure. A typical Map Sum Spectra of a cast George II Contemporary Circulating Counterfeit with Zinc (Zn) instead of Tin (Sn) in the assay and Lead (Pb) normally seen >1% and normally in the 1-10% range is seen in the next Figure 11-3 (c) for this cast coin. Too much Pb creates spit-out of the copper (Cu)/lead (Pb) mixture from the casting mold. Sometimes we may see Pb up to 15% from my previous research with casts from this CCC Family. Lead in this example is >1% but on the low end here at 1.14%. This confirms what the author calls the Mossman/Smith empirical formula for George II English/Irish CCC Halfpence assays (23). Compare the similar nebulae pattern to R.A. Scott's dendritic cast microstructure example seen in Figure 11-6.



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Si	K series	0.12	0.00093	1.61	0.09	SiO2	Yes	
S	K series	0.07	0.00064	0.70	0.07	FeS2	Yes	
Cl	K series	0.04	0.00035	0.35	0.06	NaCl	Yes	
Fe	K series	0.09	0.00092	0.53	0.08	Fe	Yes	
Cu	K series	12.39	0.12395	89.43	0.40	Cu	Yes	
Zn	K series	0.87	0.00866	6.23	0.26	Zn	Yes	
Pb	M series	0.11	0.00104	1.14	0.31	PbTe	Yes	
Total:				100.00				

Figure 11-2 (c) Map Sum Spectra of a 1739 cast George II Contemporary Circulating Counterfeit with Zinc (Zn) instead of Tin (Sn) in the assay and Pb normally seen >1% and normally in the 1-10% range. A brass lead cast specimen. Too much lead (i.e., >15%) can create spit-out of the copper/lead mixture from the casting mold. Sometimes we may see Pb up to 15%. This confirms what the author calls the Mossman/Smith empirical formula for George II English/Irish CCC Halfpence assays (23). Iron (Fe) is a probable ore carry-over contaminant and the chlorine (Cl), sulfur (S) and silicon (Si) are your typical environmental surface contaminants. Casts in this CCC series can either be cast mold with copper, bronze, brass or brass/bronze mixtures with Pb normally 1-10% from my research with some of these results posted in my book Forgotten Coins (21).

Specimen #3 1743 English Cast George II Contemporary Circulating Counterfeit

Figure 11-3 (a) Obverse (top photo) and reverse images of the 1743 English Cast CCC Halfpence

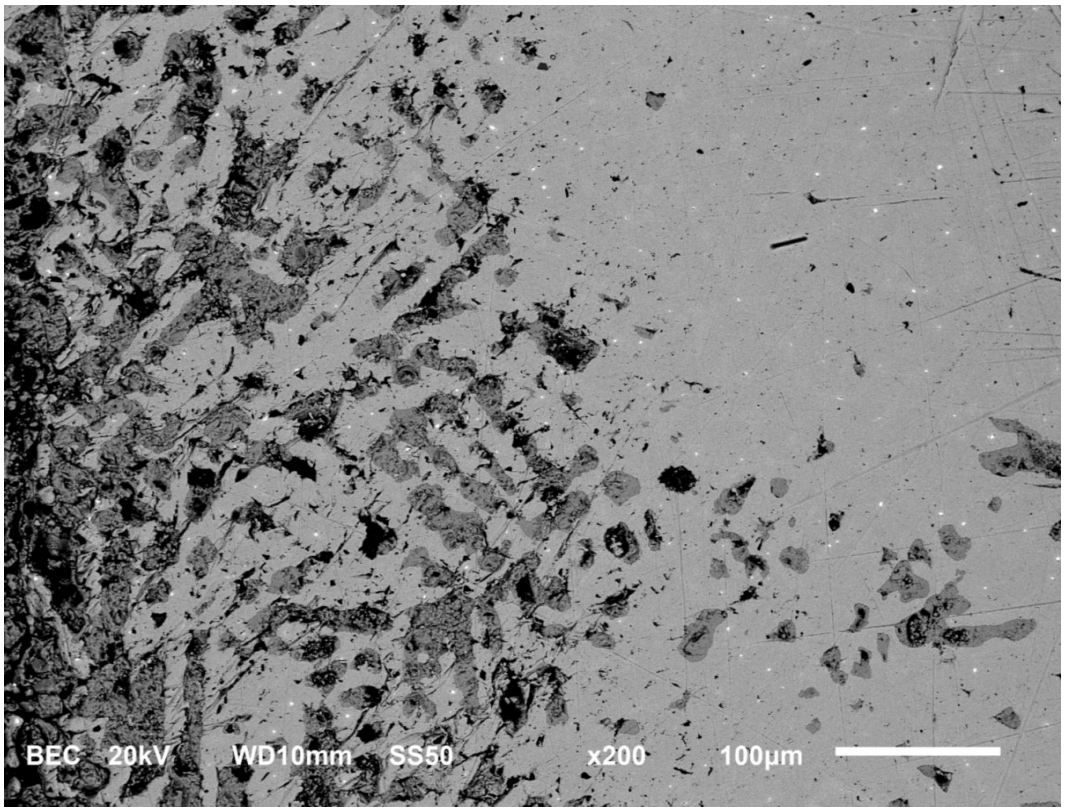
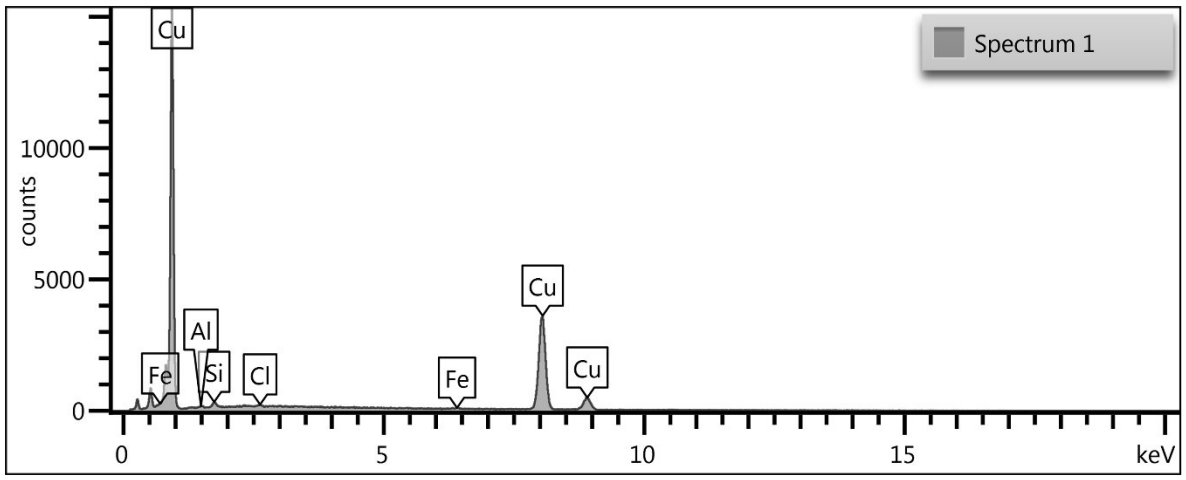


Figure 11-3 (b) SEM Micrograph Microstructure of 1743 English Cast George II Contemporary Circulating Counterfeit indicating a dendritic cast microstructure. Similar to the 1730 cast specimen above in its dendritic microstructure Figure 11-1 (b) and Map Sum Spectra Figure 11-1 (c). Also, an interesting Map Sum Spectra of the assay in Figure 11-3 (c) below indicating no tin (Sn), lead (Pb) or zinc (Zn) in the alloy mix. This is contradictory to current numismatic information that at rarely George II casts can be made up of just a high copper (Cu) assay. Lead is normally added to lower the boiling point of a Cu/Pb mixture to make it easier to cast in a casting mold. Not in this case. It can be argued that more sampling target points are necessary to verify the absence of lead in this contemporary circulating counterfeit. Counterfeiters lacking striking equipment and working dies, but only sand-casting molds seem to have no choice but to cast even high copper assay issues with no lead, zinc or tin. Obviously more samples need to be tested. The SEM Micrographs confirm this example, and the 1730 specimen are both cast from viewing their SEM Micrographs Compare the similar nebulae pattern to R.A. Scott's dendritic cast microstructure example seen in Figure 11-6. In the Mossman/Smith research of casts no SEM Photomicrographs microstructure was posted in their study. However, most die struck specimens are from my experience primarily high copper assay pieces with very low lead (<1%) and low percentages of other foreign metals. This area needs more research of this SEM/EDS three-tier approach for cast George II halfpence issues.



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Al	K series	0.02	0.00017	0.43	0.09	Al2O3	Yes	
Si	K series	0.07	0.00059	1.03	0.08	SiO2	Yes	
Cl	K series	0.04	0.00031	0.31	0.06	NaCl	Yes	
Fe	K series	0.05	0.00047	0.27	0.08	Fe	Yes	
Cu	K series	13.67	0.13673	97.96	0.16	Cu	Yes	
Total:				100.00				

Figure 11-3 (c) Map Sum Spectra of 1743 English Cast George II Contemporary Circulating Counterfeit from a Polished Area. Interesting analysis of a high copper assay with no tin, zinc or lead so the idea of a cast George II must be always a leaded bronze (Cu/Sn) and/or leaded bronze (Cu/Sn)/brass (Cu/Zn) mixture may possibly not be always correct as per Mossman/Smith (23). More target points may be necessary to verify the absence of lead. The Iron (Fe) probably at this level (<1%) a mining ore contaminant carry-over. Even after the coin's surface was polished silicon (Si) and Chlorine (Cl) remain as common surface environmental contaminants. Aluminum may have been picked up from the polishing event.

Specimen #4 1775 English Struck George III Contemporary Circulating Counterfeit

Figure 11-4 (a) Obverse (top photo) and reverse images of the 1775 English Struck CCC Halfpence

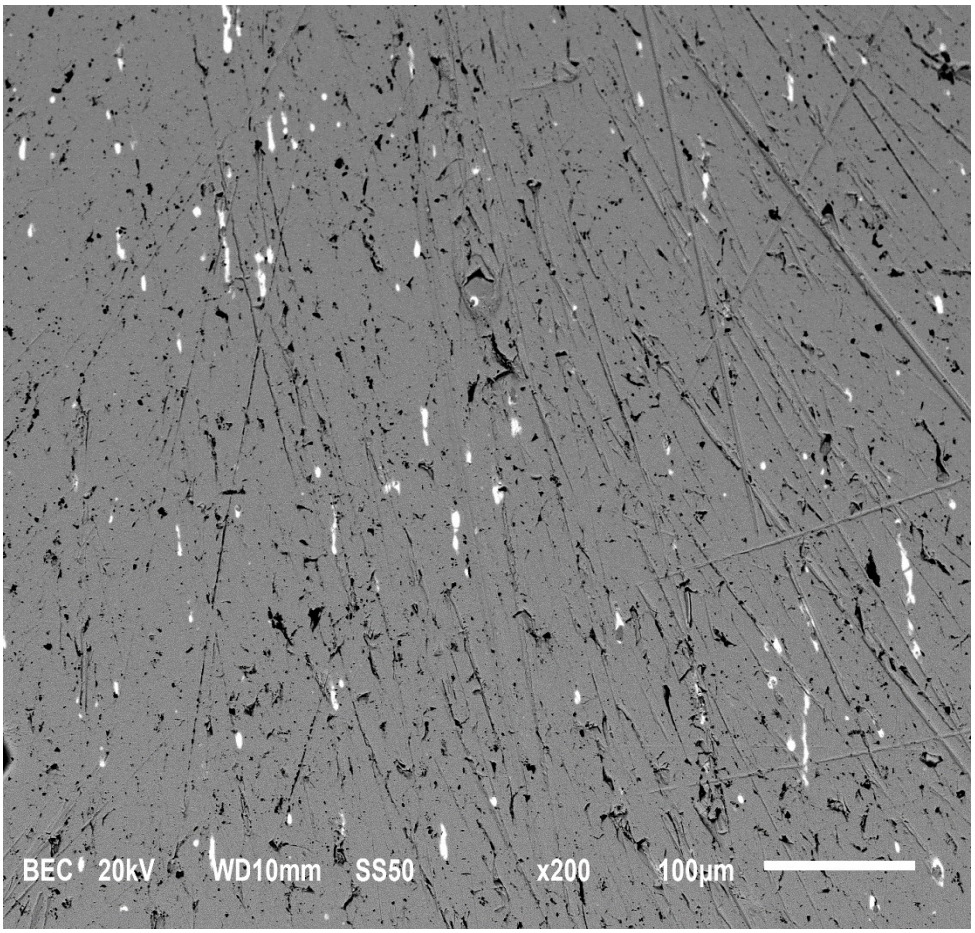
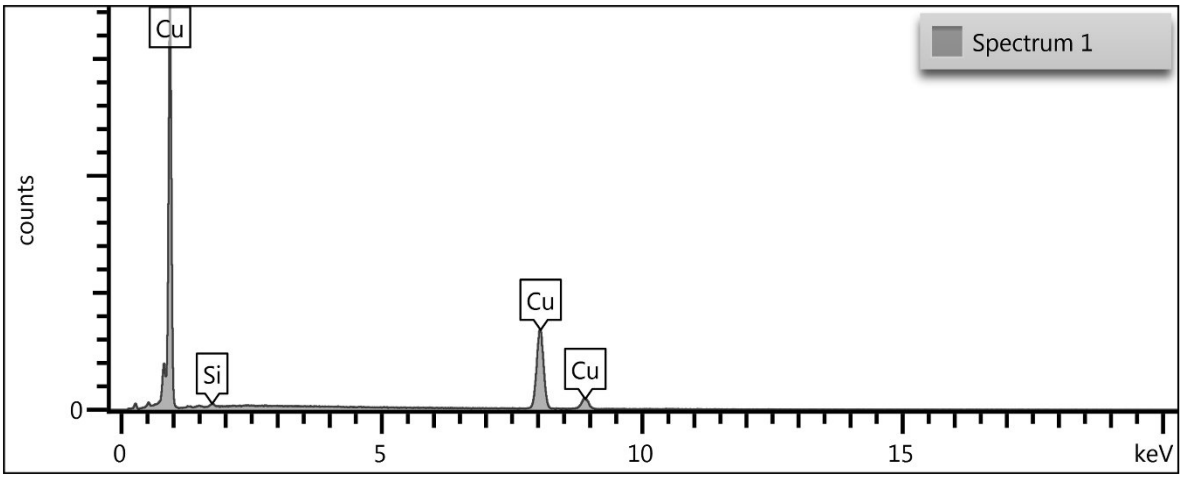


Figure 11-4 (b) SEM Microstructure Micrograph of the 1775 Struck English CCC Halfpence. Magnification 200X. A twin line struck microstructure. No Point & ID was performed as these SEMs in this Phase III were strictly for cast/struck SEM Micrograph Microstructure confirmation and since a Map Sum Spectra was performed at the target shot area as with the other four coins treated in this Phase III. The coin's area was polished for this target shot to help remove most of the common surface contaminants. Its Map Sum Spectra is seen in the following Figure 11-4 (c). Note the difference in the SEM Micrograph profile of this micrograph of a struck piece and the three previous cast micrographs. See the similarity to Craddock's SEM die struck micrograph in Figure 8.29 in his reference (25). Refer to page 83. Compare the micrographs of this 1775 struck halfpence also with the next example a1782 struck Irish Halfpence. Craddock mentions in his SEM micrograph (page 83) noting the characteristic flow lines running across the image and striations running down the image. Again, much different than a dendritic cast SEM micrograph (i.e., photomicrograph seen earlier with these cast issues with their distinctive nebulae patterns.) See also Figure 12-7.



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Si	K series	0.05	0.00040	0.66	0.08	SiO2	Yes	
Cu	K series	14.92	0.14917	99.34	0.08	Cu	Yes	
Total:				100.00				

Figure 11-4 (c) Map Sum Spectra of 1775 English Cast George II Contemporary Circulating Counterfeit from a Polished Area. Silicon (Si) is a surface contaminant from manufacturing or a geological ore carry-over metal from copper production. An interesting assay of almost pure copper at 99.34% which in many cases is reflective of 18th C imported CCCs copper assays (i.e., Cu levels >98%) based on my studies (21). The polished area removed all the commonly seen trace surface contaminants such as chlorine (Cl) and sulfur (S) at levels generally <1%. This author never really considered these George II or George III CCC Family issues a so-called melting pot of mixed metals. As an example, in Forgotten (21) the author examined several Evasions and George II/III CCCs. In most cases a high nearly pure copper assay as in this example was the usual assay and normally Copper (Cu) with values >98.0% were the norm in the assays. Copper was in no short supply in England particularly in these CCC manufacturing houses. Their profits were in their mass production numbers and the continual need of the poor working-class continually needing small denomination change. This copper money rather than in silver and gold denominations kept their poor livelihoods going in these times in England as well as in Ireland in the 17th/18th/early 19th centuries.

Specimen #5 1782 Irish Struck George III Contemporary Circulating Counterfeit

Figure 11-5 (a) Obverse (top photo) and reverse images of the 1782 Irish Struck CCC Halfpence

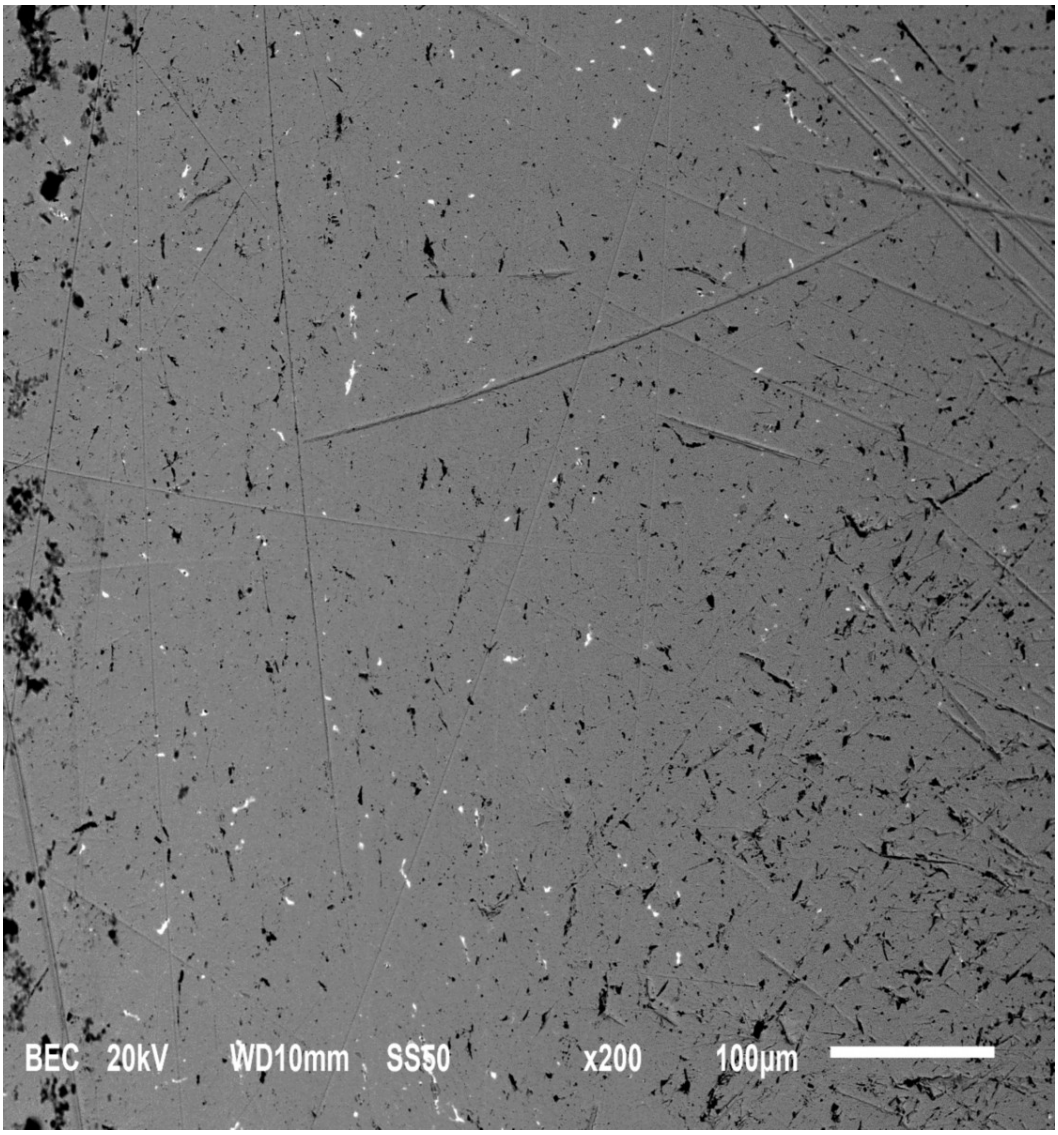
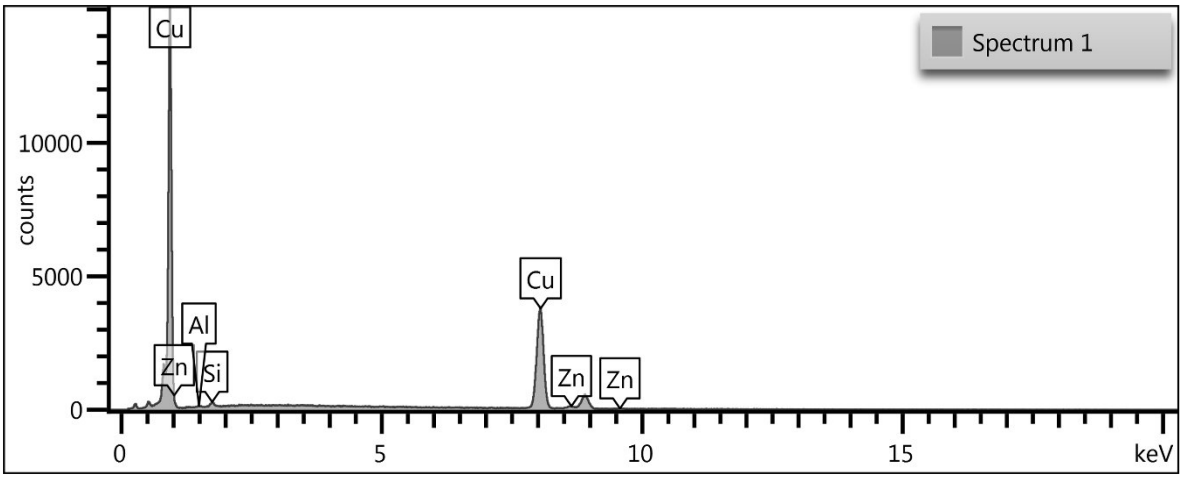


Figure 11-5 (b) SEM Microstructure Micrograph of the 1782 Struck Irish CCC Halfpence. Magnification 200X. A twin line struck microstructure. Straight line striates as seen with the 1775 specimen – compare this to Craddock's Figure 12-7 twin line struck microstructure illustration. No Point & ID was performed as these SEMs in this Phase III were strictly for cast/struck SEM Micrograph Microstructure confirmation and since a Map Sum Spectra was performed at the target area as with the other four coins treated in this Phase III. The coin's area was polished for this target shot to help remove most of the common surface contaminants. Its Map Sum Spectra is seen in the following Figure 11-5 (c).

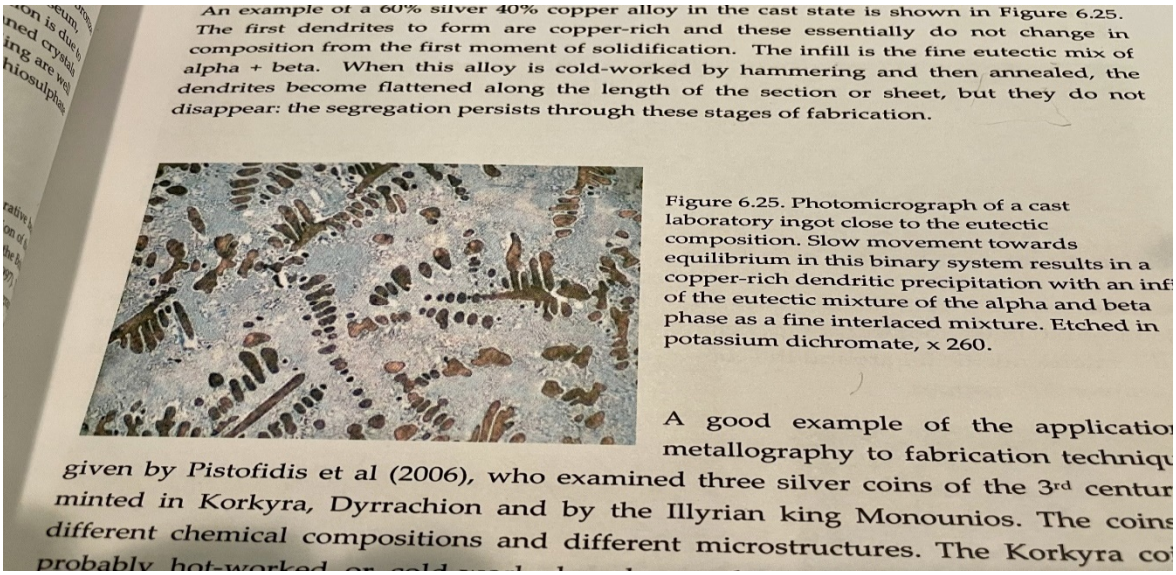


Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Al	K series	0.02	0.00011	0.26	0.08	Al2O3	Yes	
Si	K series	0.06	0.00051	0.85	0.07	SiO2	Yes	
Cu	K series	14.16	0.14163	96.44	0.25	Cu	Yes	
Zn	K series	0.36	0.00359	2.44	0.23	Zn	Yes	
Total:				100.00				

Figure 11-5 (c) Map Sum Spectra of the 1782 Irish Struck George III Contemporary Circulating Counterfeit from a polished area of the coin. In this case some trace Zinc (2.44%) did make its way into the high copper alloy of this 1782 Irish CCC Halfpence unlike the pure copper assay we saw previously in Figure 11-4 (c) for the 1775 struck English CCC. Silicon (Si) is probably from a manufacturing ore source from copper production and the aluminum may be from the polishing event and is not considered by the author as part of the original alloy for this CCC. So, a very low zinc brass (Cu/Zn) 1782 Struck Irish CCC Halfpence. This zinc is random and can be considered being of a melting pot scenario. The author does not believe this level of zinc being >1% is from an ore contamination carry-over but was added during the planchet making process under a melting pot scenario (i.e., the zinc being added via various scrap metal additions into a melting pot to make these CCCs). However, as previously indicated once a much larger database is created the author believes most struck George III CCC halfpence will display copper assays >98%. When we do see a melting pot situation most other metals like zinc and tin will probably be <10% in the assay from my research up to this point in time.

David A. Scott's Cast Microstructure SEM Micrograph Illustration and Explanation of Dendritic Growth of Copper Alloys

As an example, from a standard reference in this science of Metallography the author is supplying this cast dendritic representation of a 60% silver/40% copper alloy in the cast state. This same type of nebulae dendritic growth is seen in all three high copper cast alloys in this study. This was represented in Scott's reference (22) on page 53 in his Figure 6.25. This is pictured below as Figure 11-6 to confirm its similar microstructure patterns seen in our three cast coins illustrated in Figures 11-1-3 (b) the SEM Micrographs (i.e., photomicrographs) of the 1730, 1739 and 1743 cast coins.



An example of a 60% silver 40% copper alloy in the cast state is shown in Figure 6.25. The first dendrites to form are copper-rich and these essentially do not change in composition from the first moment of solidification. The infill is the fine eutectic mix of alpha + beta. When this alloy is cold-worked by hammering and then annealed, the dendrites become flattened along the length of the section or sheet, but they do not disappear: the segregation persists through these stages of fabrication.

Figure 6.25. Photomicrograph of a cast laboratory ingot close to the eutectic composition. Slow movement towards equilibrium in this binary system results in a copper-rich dendritic precipitation with an inf of the eutectic mixture of the alpha and beta phase as a fine interlaced mixture. Etched in potassium dichromate, x 260.

A good example of the applicatio metallography to fabrication techniqu given by Pistofidis et al (2006), who examined three silver coins of the 3rd centur minted in Korkyra, Dyrrachion and by the Illyrian king Monounios. The coins different chemical compositions and different microstructures. The Korkyra co probably hot-worked or cold

Figure 11-6 Scott's excellent SEM Micrograph Microstructure (i.e., photomicrograph) of a 60% silver/40% copper alloy with similar nebulae patterns seen in all three Cast George II counterfeits in Phase III. This type of pattern unlike in twin line struck issues as with the 1775 & 1782 CCCs are visually very different. Scott's description of Figure 6.25 reads a photomicrograph of a cast laboratory ingot close to eutectic composition (i.e., a eutectic composition is a homogeneous mixture of two or more substances in specific proportions that has a lower melting point than any of its components). In this case silver and copper. Slow movement towards equilibrium in this binary (i.e., two metal) system results in a copper-rich dendritic precipitation with an infill of the eutectic mixture of the alpha and beta phase as a fine interlaced mixture. Etched in potassium dichromate (i.e., for an enhanced color overview) with the SEM magnification here at 260X. Scott also notes when this alloy is cold worked by hammering and then annealed, the dendrites become flattened along the length of the section or sheet, but they do not disappear: the segregation persists through these stages of fabrication. The author has seen high copper casts or copper in a binary (i.e., two metal) systems display these similar dendritic nebulae patterns. Again - Compare this photo of Scott Figure 11-6 to the three SEM photomicrographs of 1730, 1739 & 1743 coins of Figures 11-1-3 (b) above in the Phase III study.

Phase IV SEM/EDS Analysis of an 1802 Lima Mint Peruvian Regal 90% Silver Example. Classified as KM# 95 (23)

Introduction

For completeness in this study, the same analytical methods previously used for the two regal looking off-metal CCC character Kleeberg type two reales specimens (Specimens B & C) will now be used on this 1802 Lima Peruvian two reales 90% regal example. This coin is pictured in Figures 3-1 and 3-2. The analytical testing performed will be the same triple-tier SEM/EDS type of analysis. This involved:

- For cost considerations only one area of the **unpolished coin** will be analyzed. Any type of copper debasement or intentional counterfeiting will be borne out by the analysis which is unlikely since the coin passes all the metrological/physical data for this regal example. According to the KM#95 reference listing the coin at the time of production had a weight at 6.7668 grams. Its Ag assay was 89.6% Ag. Obverse of the coin depicts a bust of Charles IIII facing right with a reverse legend of HISPAN*ET*IND*REX* with a cojoined ME mintmark indicating Lima, Peru with an assayer IJ for this example.
- To perform a SEM image of the surface at the same level as with other test coins in this study and for this example the standard 200X magnification was selected.
- To generate a Map Sum Spectra for one target area only.
- To generate a Point & ID spectrum analysis normally performed at the 1000X magnification level to confirm the uniformity of high silver and low copper in the coin's metal assay.

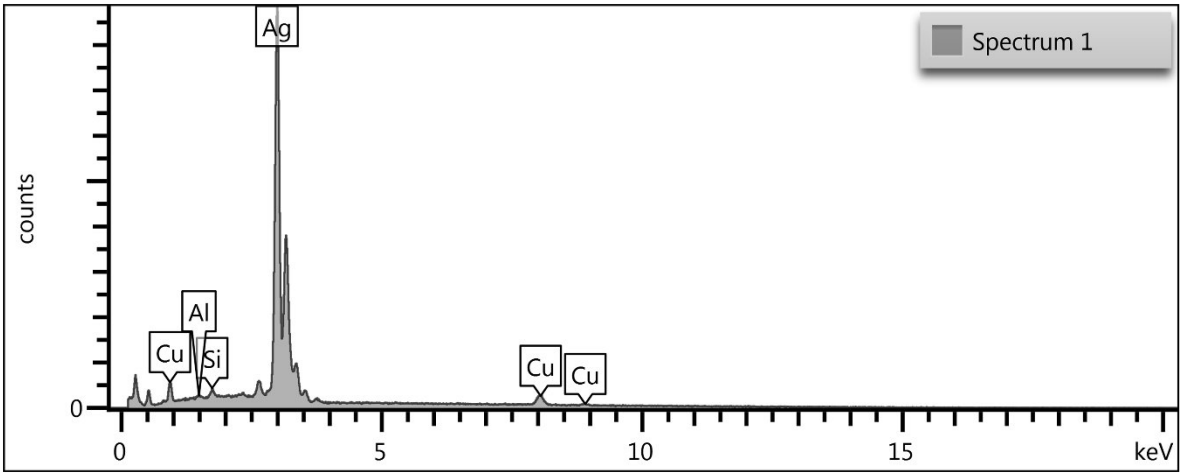
Results

The results clearly show that the specimen has no similarity to the two off-metal CCCs previously analyzed and labeled B & C. The Map Sum Spectra, SEM images at both 200X and 1000X magnification will be pictured and discussed and a Point & ID of three target spectrum areas will be discussed. Previously in the D.A. Scott reference (22) we saw how the dendritic nebulae pattern was like all three George II Halfpence cast specimens. In this case we will picture from a well-known scientific investigation forgery encyclopedia reference Paul Craddock's Scientific Investigation of Copies, Fakes and Forgeries (25) illustrating a struck coin's SEM photomicrograph in Figure 8.29 in this Craddock reference which is pictured in this Phase IV section. This was done as a reference comparison to this 1802 Peruvian Lima 2 Reales and to the other struck specimens in this study namely Coins B & C and the 1775 and 1782 English and Irish die struck halfpence. See Figure 12-7 on page 83.

The results will be in the typical order for this regal 1802 Lima, Peru 2 Reales for the three-tier SEM/EDS methodology performed at MSU:

- Map Sum Spectrum
- SEM Micrographs at 200 X and 1000X
- Point & ID Spectrum Analysis for three different B&W shaded target areas.

Map Sum Spectra: 1802 Regal Lima Paru 2 Reales (Coin pictured in Figures 3-1 & 3-2)



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard	Standard Calibration Date
Al	K series	0.02	0.00014	0.28	0.07	Al2O3	Yes	
Si	K series	0.05	0.00039	0.58	0.06	SiO2	Yes	
Cu	K series	0.61	0.00611	5.64	0.22	Cu	Yes	
Ag	L series	9.68	0.09679	93.50	0.24	Ag	Yes	
Total:				100.00				

Figure 12-1. 1802 Regal Lima Peru Two Reales (KM#95). Listed with a regal weight of 6.7768 grams and with 89.6% silver alloy composition in a silver/copper assay we see good agreement with this KM-listed specification. We normally see silver (Ag) values higher than listed as in this case with 93.5% Ag to the KM recorded silver assay of 89.6% Ag. This is a good example of silver surface enrichment. The surface enrichment of archaeological silver–copper alloys has been recognized for many years (17). The author has seen many examples, but this process can take at least over a century to develop from my research and with the right environmental conditions. The copper (Cu) is added solely for alloy hardness as silver is a soft metal but not as much as gold. The silicon (Si) and aluminum (Al) are surface contaminants. This level of silver (93.5%) was never seen at this elevated level or even close to 89.6% Ag in Coins B & C, so it was important to analyze a silver regal two-reales coin as a representative example of a legitimate issue and then compare it to these two contemporary circulating counterfeit coins B & C. The results are self-explanatory.

SEM Micrograph 200X Magnification: 1802 Regal Lima Paru 2 Reales (Pictured previously in Figure 3-1 & 3-2)

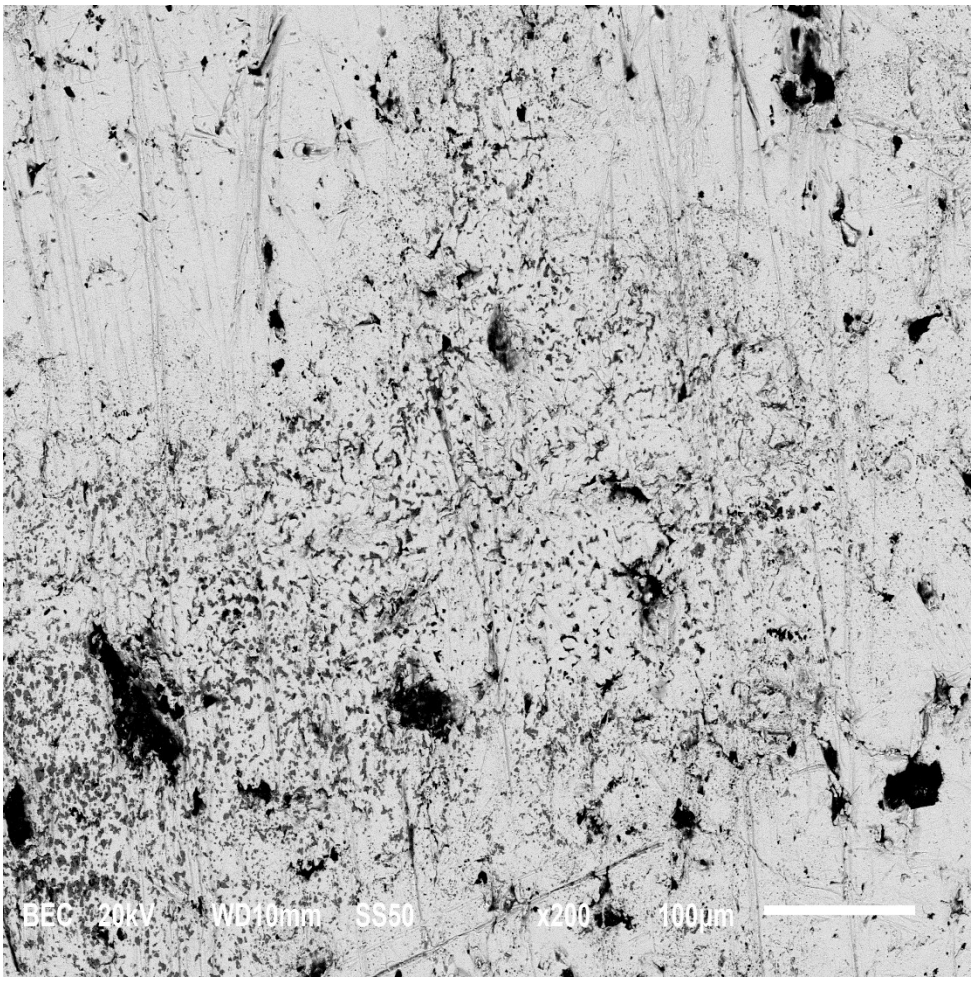


Figure 12-2 SEM Micrograph 200 X magnification indicating a twin line microstructure and from a struck coin operation. Straight striate seen throughout the microstructure. Some jigsaw patterns are seen clearly in the lower right area of the photomicrograph. Most jigsaw patterns are masked by these dark silver and copper sulfide areas – see Figures 12-5-6.

SEM Micrograph 200X Magnification: 1802 Regal Lima Paru 2 Reales (Coin Pictured in Figure 3-1 & 3-2)

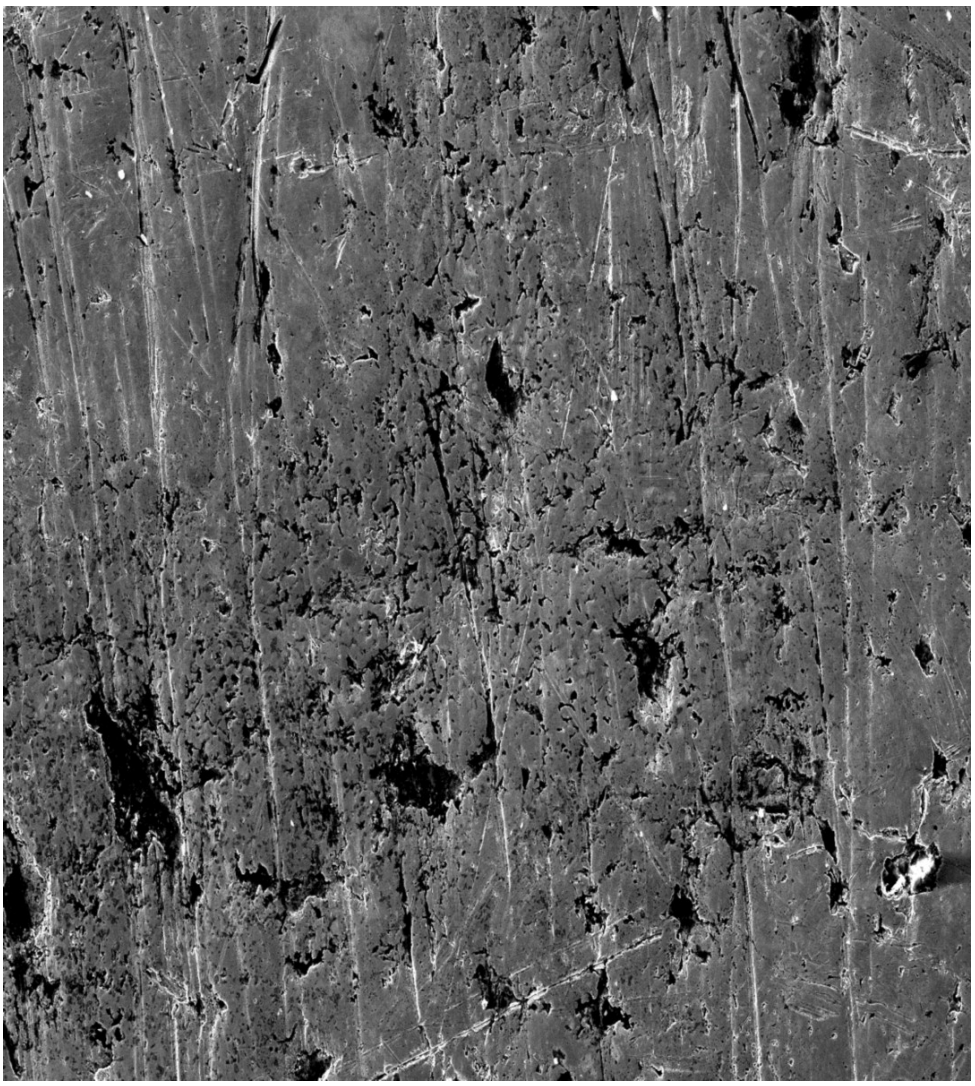


Figure 12-2 (a) SEM Micrograph 200 X magnification indicating twin line microstructure and from a struck coin operation. Identical to Figure 12-2 but of a darker contrast. As Craddock indicates, note the characteristic flow lines running across the image and striations running down the image, caused as the metal is forced to flow over the cut edge of the die during the actual striking process. See Figure 8.29 from Craddock's reference book pictured below in this Phase IV section as a photomicrograph comparison of a struck coin issue from Craddock's reference book on Scientific Analysis on Forgeries (25). See Figure 12-7 on page 83.

SEM Micrograph 1000X Magnification: 1802 Regal Lima Paru 2 Reales (Pictured previously in Figure 3-1 & 3-2)

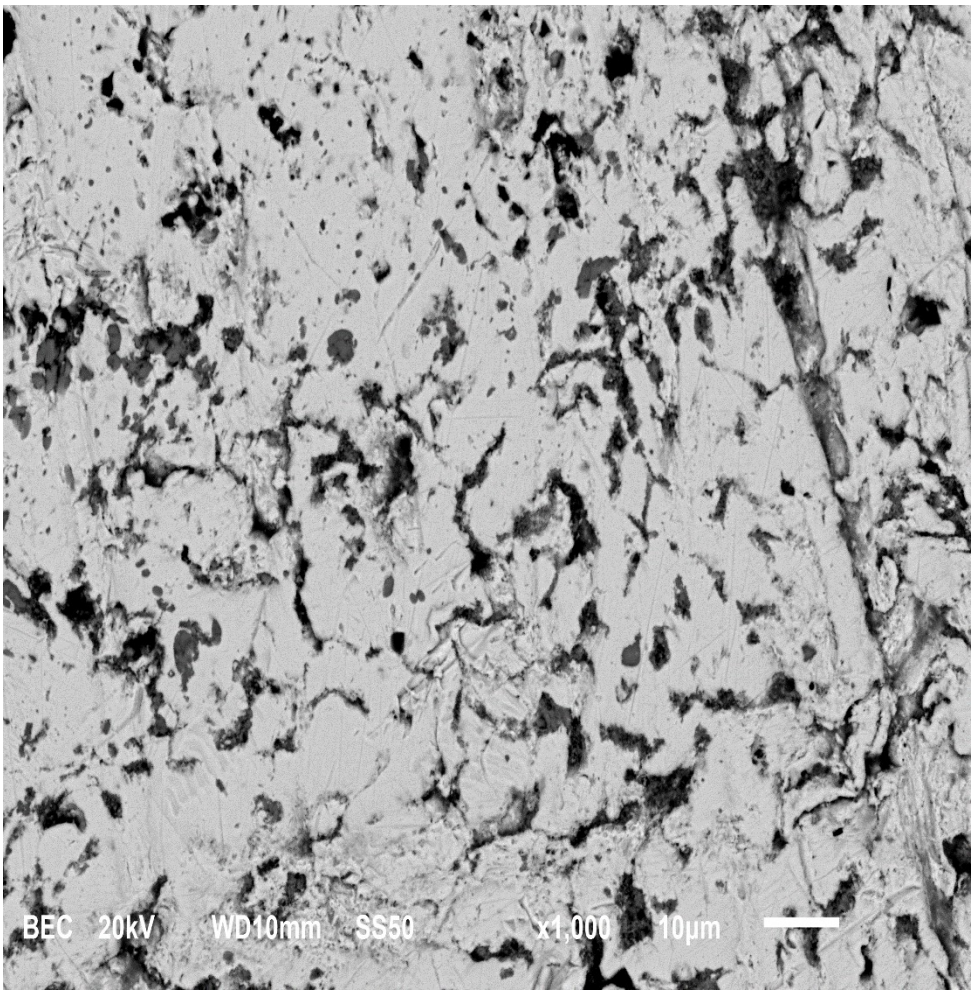


Figure 12-3 SEM Micrograph at a 1000 X magnification indicating twin line microstructure and from a struck coin operation. Granted at this magnification level the striations are all but lost but on the right side of the photomicrograph we have a huge view of one running northwest/southeast. We also see in more clearly here a jigsaw like pattern also diagnostic of a die struck microstructure. We will see in the Point & ID in the next set of analyses (Figures 12-4-6) after a 1000X dark image of this same area seen in Figure (Figure 12-3 (a)). The black areas seen here in this light contrast image are notably copper areas intermixed with the white areas being that of silver areas based on the Point & ID analyses.

SEM Micrograph 1000X Magnification: 1802 Regal Lima Paru 2 Reales (Pictured in Figure 3-1 & 3-2)

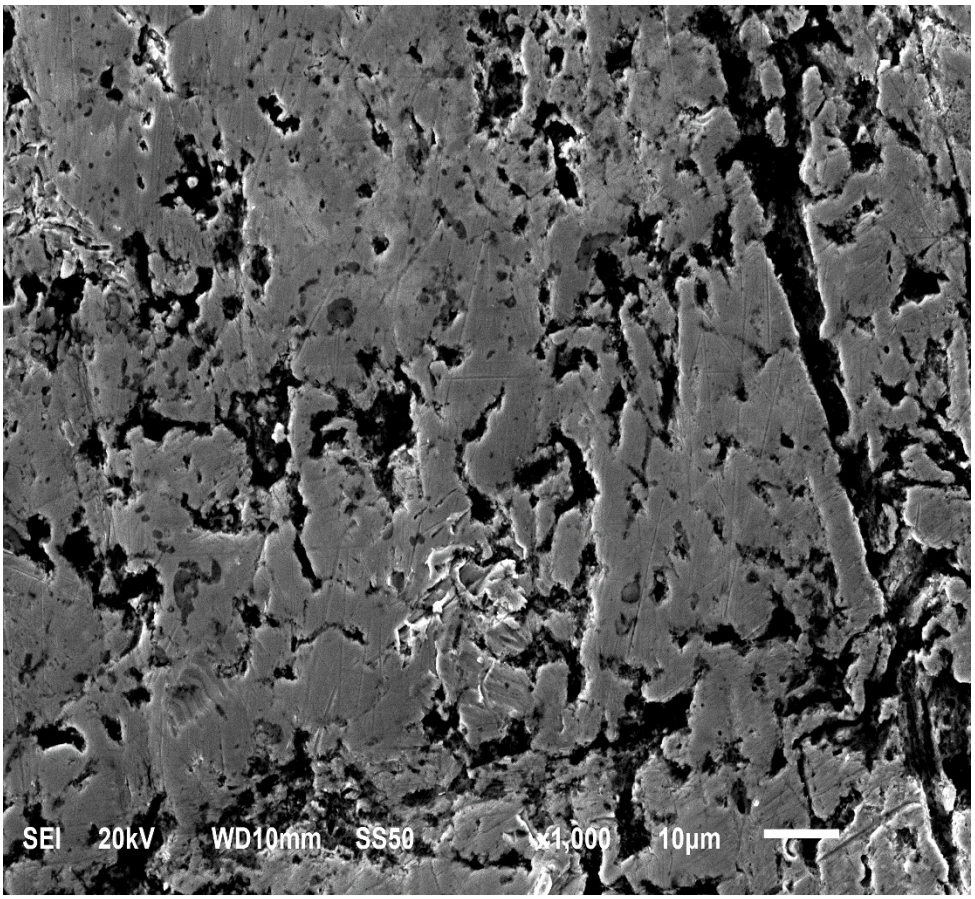


Figure 12-3 (a) SEM Micrograph 1000 X magnification indicating twin line microstructure and from a struck coin operation. The same photomicrograph as seen in Figure 12-3 but in a darker contrast and note the better clarity of these striations than the lighter contrast seen in Figure 12-3 above on page 78 of the same coin area. The Point & ID in the next three figures we take a light contrast photo and try to identify the different shades of black & white in the photo. We will basically see three metals: silver, copper and sulfur metal being the sole surface contaminant. This coin was not polished for two major reasons. The first was to illustrate to the reader how silver surface readings can exceed the numismatic silver levels of production from historical records due to the silver surface enrichment process (17) which we have seen in the Map Sum Spectrum analysis. Second – to record any common surface contaminants on a 90% silver regal from this period (i.e., late 18th C/early 19th C) and in this case, it may be both copper sulfide and silver sulfide. Further analysis would be required but whether it's CuS or AgS is irrelevant since our primary investigative goal of this paper is the comparison of regal vs. non-regal (i.e., contemporary circulating counterfeit) issues and their metal assays. The jigsaw like patterns are more easily seen on the lighter contrast view (Figure 12-3).

Point & ID: 1802 Regal Lima Paru 2 Reales (Pictured in Figure 3-1 & 3-2). Spectrum Areas 1, 2 & 3

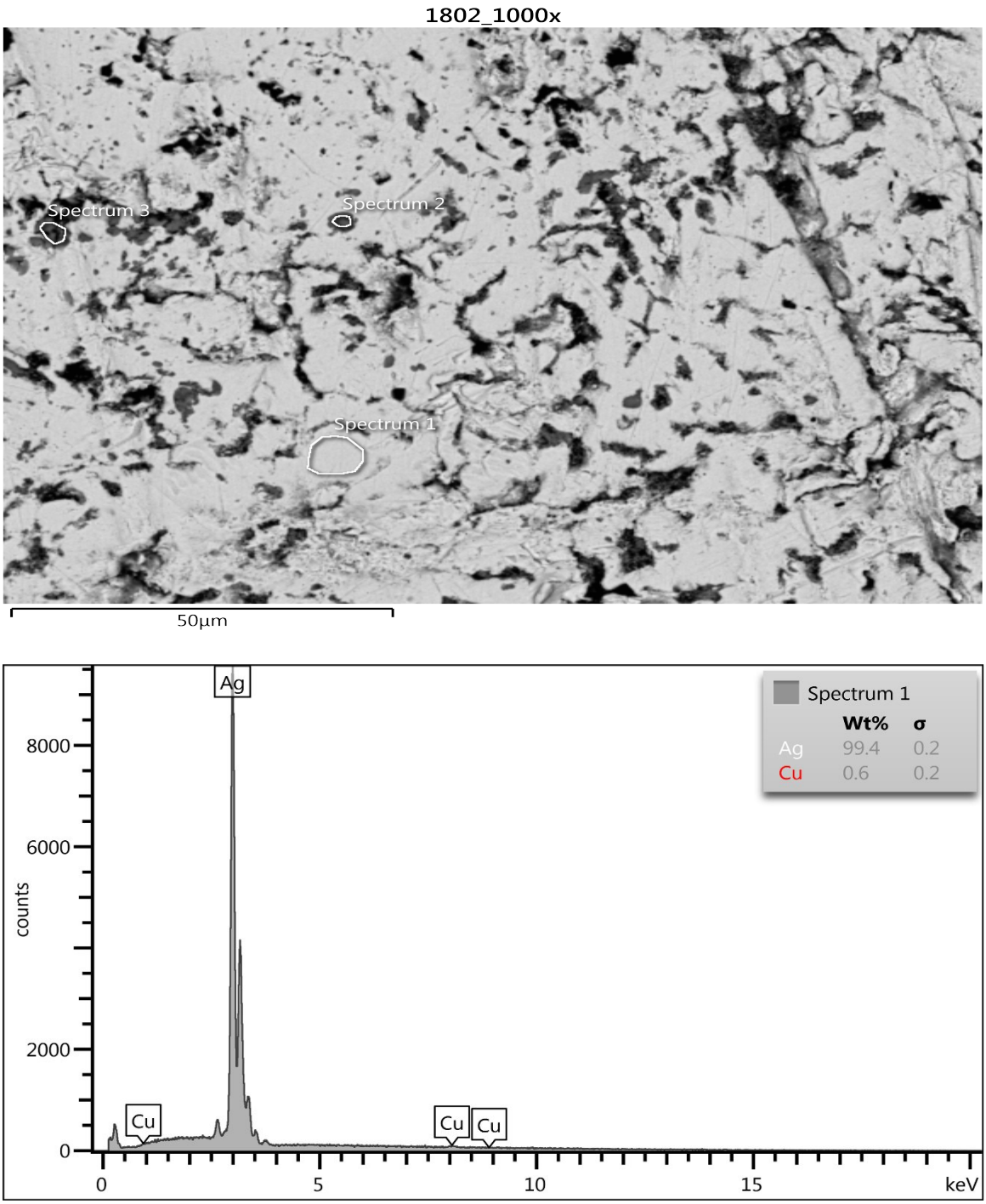


Figure 12-4. The spectrum 1 area above shows almost pure silver at 99.4% in the white area. Logically the next inquiry would be what metal, or metals are in the darker area? This level of silver (99.4%) was never even closely quantitatively achieved with Coins B & C in any Point & ID spectrum.

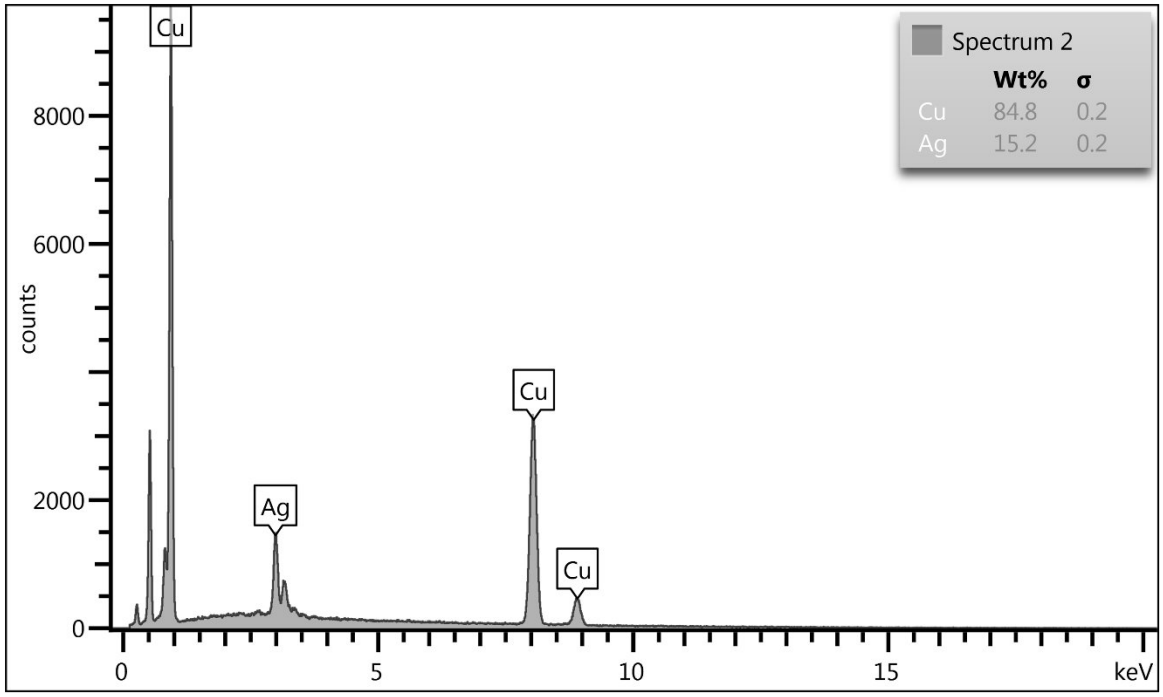


Figure 12-5. This spectrum 2 area from Figure 12-4 showing the darker area is predominantly copper (Cu) in this spectrum area with silver (Ag) also be inter-mixed in this area.

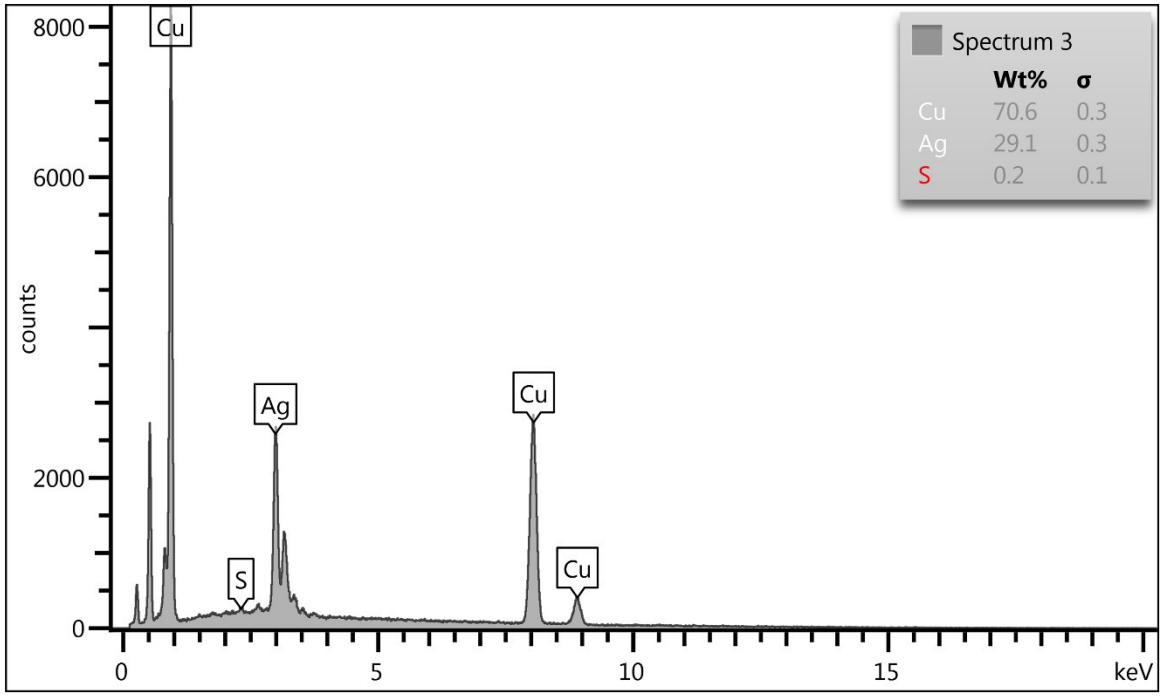
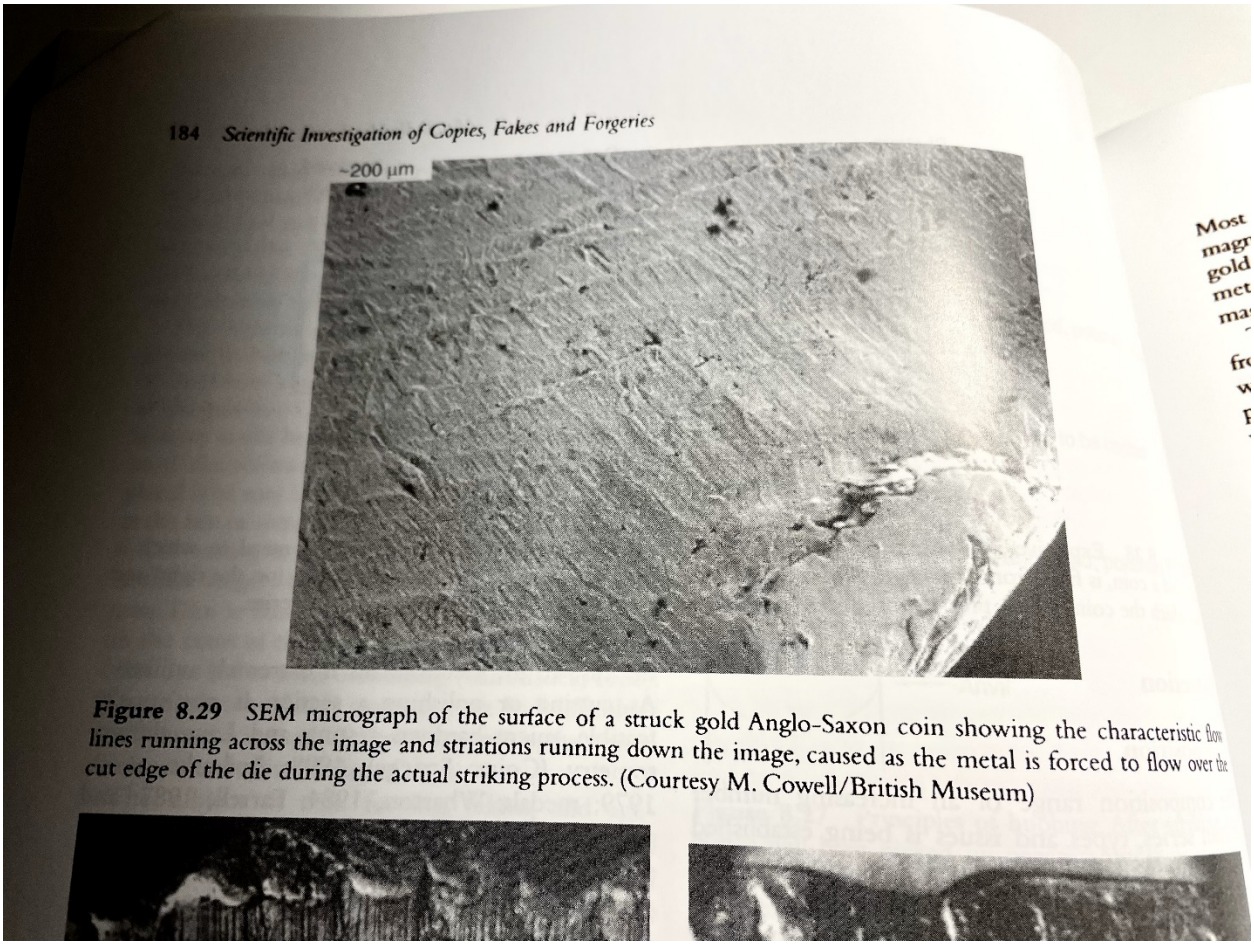


Figure 12-6. A third dark area was analyzed as Spectrum 3 and in this case, we do pick up Sulfur (S) a common surface contaminant. Expect copper sulfide and silver sulfide to be present in this surface corrosion layer for these regal two reales. Expect the silver level to be slightly elevated in most cases with a silver/copper regal at 90% silver being several centuries old due to the silver surface enrichment effect. Expect the inner coin's core to be void of sulfur and see more a ~90% silver/10% copper ratio as per the coin's original alloy mix when made in 1802 in Lima Peru as per the KM# listing for this regal issue.

Figure 12-7 (below). **Paul Craddock's Figure 8.29** from his Scientific Investigation of Copies, Fakes and Forgeries (25). SEM micrograph of the surface of a struck gold Anglo-Saxon coin showing the characteristic flow lines running across the image and striations running down the image, caused as the metal is forced to flow over the cut edge of the die during the actual striking process. A twin line type microstructure. This image based on the 200-micrometer magnification level reading at the top left of the photo seen below by Craddock is like the 200X magnification level photomicrographs taken at MSU at this SEM magnification level. We can see at 1000X the multiple striations on the coins surface are difficult to view and become almost individualistic in their size to the viewer (Figures 12-3 & 12-3 (a)). It would be interesting sometime in the future to have different coins of different mints and periods to have their surfaces SEM imaged at this preferred 200X level for cross comparisons as twin line coin struck microstructures as compared to dendritic casts as previously seen in this paper.


184 Scientific Investigation of Copies, Fakes and Forgeries
~200 µm
Figure 8.29 SEM micrograph of the surface of a struck gold Anglo-Saxon coin showing the characteristic flow lines running across the image and striations running down the image, caused as the metal is forced to flow over the cut edge of the die during the actual striking process. (Courtesy M. Cowell/British Museum)

Phase IV Conclusion

The results of the single target shot of the 1802 Lima Peru two reales coin pictured in Figures 3-1 and 3-2 show convincingly its regal with silver levels exceeding the regal silver historical level listed in Krauss-Michler (KM#95) at 89.6% silver. This was due to silver surface enrichment effects with time which produces this very thin enrichment layer on the surface of this unpolished coin. Polishing this coin would likely remove the silver surface enrichment area. As other experiments have shown below this silver enrichment layer, we do expect the silver value to drop to 90% or closer to the KM #95 listed silver value of 89.6%. SEM micrographs at 200X and 1000 X magnification levels illustrated a twin line microstructure, or this striated surface we see in Craddock's book in Figure 8.29. There are other references which display this striated and/or jigsaw like surface feature as compared to a cast dendritic nebulae pattern, but this is sufficient for this paper. Numismatists needing more information can explore the Internet and seek out this Craddock reference along with D.A. Scott's books on coins and microstructure. For the Point & ID analysis this author also asked MSU to illustrate the different areas of silver (i.e., white areas) and copper (i.e., darker areas) as illustrated in the Phase IV results. At the surface we can also expect both silver sulfide and copper sulfide, both being dark colored compounds, to also be represented by these darker regions in the SEM micrographs. The **important point** here is neither Coin B nor Coin C had silver levels this high in any of their Map Sum Spectrum or Point & ID analysis from any of their three random target points performed for each coin.

Conclusion

This paper contains four Phases of analysis in a three-tier type analysis utilizing SEM/EDS analysis. This three-tier system involves first creating a **Map Sum Spectrum** of a Target area of the coin. We then look at the coin's microstructure utilizing a **SEM Micrograph** at various magnification levels. The 200X magnification level seems to be the most helpful after looking initially at levels of 200X, 1000X and 3000X with MSU personnel. Finally, SEM Micrographs contain different shaded areas of the SEM micrograph, and these were selected for metal assay determinations which were called spectrum areas and were also reported. This was called the **Point & ID Analysis**. In this case the 1000X magnification level seems to be the best magnification level in selecting the different spectrum areas but in other studies this may be coin and alloy specific. Once we had established this three-tier approach: **Map Sum Spectrum** (i.e., Table 1 for Coin B)/**SEM Micrograph** (i.e., Figure 4-1 for Coin B)/**Point & ID Analysis Spectrums** (i.e., Figure 4-2 & Figure 4-3 Spectrum Area #1 for Coin B) this three-tier approach is then utilized for each target area. This three-tier approach was then performed in each of the four following Phases of Analysis:

Phase 1: Performed three target (i.e., spot) areas of Coin B and Coin C in an **unpolished** state. Each target area utilizes the three-tier analytical approach: Map Sum Spectra/SEM Micrograph/Point & ID Analysis Spectrums. As mentioned previously due to the high cost of analysis with SEM/EDS at just over $100/hour and previous discussions with the MSU Material Analysis Laboratory (MSU) it was decided to analyze just two examples of the regal motif looking Kleeberg examples. Specimens B&C were selected since both are of the same manufacturing operation as both pieces are of the same Kleeberg variety number K.19A-L37. Coin B after three target areas under this three-tier analytical approach indicated to be either a possible mercuric silvered copper host or a silver alloy heavily debased with copper. In my opinion after a three-target area search with no trace mercury (Hg) found on the surface this Coin B is likely to be a debased silver with copper host in the opinion of this author and is a struck example based on review of the SEM micrographs in each target area.

Coin C is a confirmed surface mercuric silvered silver alloy but debased with bronze (Cu/Sn) and confirmed also as Coin B by SEM Micrographs (i.e., SEM Microscopy) as struck. This is not the usual type of counterfeit host. We would expect just a mercuric silvered bronze host, but we confirm a mercuric silvered surface over a silver alloy which is then debased with bronze! The author chose to perform both unpolished and polished target point analysis since if you polish the coin more than likely you will remove the thin mercuric silver layer and therefore remove any traces of mercury on the surface. Additionally, it was quite instructive to view all the common surface contaminants on the surface that may come into play which are outside the original metal alloy compositions of Coins B & C.

Phase II: In this phase it was decided only one target area was necessary for Coins B & C in performing this three-tier analytical approach on a polished area near/on the rim area of the coins (i.e., the third side of a coin – rim area). The results seen with the removal of surface contaminants in Figure 10-1 for Coin B when comparing copper and silver levels in Figure 10-1 we see copper at 30.26% and silver at 63.01% which is anything but close to regal levels at ~90% silver/~10% copper.

Conclusion (continued)

We see a high level of arsenic at 6.73% as carry-over contamination from copper production. For Coin C we see copper (45.7%), silver (40.0%), tin (11.2%), lead (2.25%) and silicon at 0.86%. Once polished the silvered mercury layer was removed as expected. With this high silver level, we then conclude silver was debased with both copper and tin (bronze mixture) and then the surface silvered with mercury as was evident from the unpolished SEM/EDS results of Phase I.

With just a surface XRF analysis with no coin surface polishing it would be very probable that we would conclude Coin C is mercuric silvered bronze host contemporary circulating counterfeit. This is an excellent example of how an in-depth three tier SEM/EDS analysis of polished/unpolished surfaces can sometimes modify a surface XRF result even with a high-end XRF benchtop instrument. In other words, with a surface XRF analysis it would be difficult to differentiate between the mercuric silver surface layer and the elevated ~40% silver in the host coin then debased with a bronze mixture only revealed after surface polishing.

Phase III: This SEM/EDS analysis consisted of the same three-tier approach of Map Sum Spectrum/SEM Micrograph Microstructure and Point & ID Spectrums of polished Cast George II Contemporary Circulating Counterfeit Halfpence and Struck George III Contemporary Circulating Halfpence. The main reason the author chose this Phase of analysis was to demonstrate the power of this three-tier analytical methodology on another counterfeit family of major importance. These coins are also of a copper alloy host like Coins B & C but without the silver. Using SEM Micrographs, we can see the dendritic nature of cast and the different photomicrographs produced by die struck pieces. These SEM Microstructures and Map Sum Spectrum do indicate that lead was not always used to lower the melting point of the cast mixtures and that there are sometimes exceptions to the Mossman/Smith empirical formula that all casts contain some levels of zinc, tin or lead. Further research is needed in this area to confirm other cast coin exceptions of just being of a high copper assay nature.

Phase IV: A legitimate (regal) 1802 Lima Peru two reales was chosen simply to show the difference of silver and copper levels when compared to our two primary coins of analysis Coins B & C analyzed in Phase I (unpolished) and Phase II (polished). In this Phase IV we see the slightly elevated level of silver at 93.5% (see Figure 12-1) compared to its historic mint made level found in KM#95 in the 19th Century Krauss/Michler Standard Catalog of World Coins (Seventh Edition) at 89.6% silver. So, this Phase IV result clearly also shows the silver surface enrichment effect (17) which normally occurs on coins this old (i.e., late 18th C/early 19th C) particularly of a metal assay of ~90% Ag/~10% Cu composition as seen by this author hundreds of times before with these regal (i.e., legitimate) Spanish American reales in all of their other denominations (i.e., 1/2R, 1R, 4R & 8R's).

This paper shows the potential value of this three-tier analytical approach. It also demonstrates that at times if permissible polished or unpolished coin surfaces will often bring different results. Using a very sophisticated in-depth triple-tier SEM/EDS analysis can provide us with more avenues of information beyond the powers of surface XRF analyses in the field of numismatics.

Glossary of Terms

Note: Some of these definitions when appropriate were obtained from the Counterfeit Eight Reales (The Un-real Reales) book produced by Robert Gurney, Gord Nichols and this author in

2013 and being sold through Amazon Books. Some other definitions were obtained from my book Forgotten Coins of the North American Colonies – 25th Anniversary also being sold on Amazon Books. The remaining definitions were obtained from the Internet or from Material Analysis papers in my library of other similar Material Analysis numismatic investigations with silver and/or copper alloys.

Arsenic (As) – In this study an element brought over by copper which was poorly manufactured as is the case when dealing with low-end type counterfeiting operations. In this study when the quantitative level of copper rose arsenic also rose proportionally. Arsenic did not behave this way or was present with silver but primarily with the presence or absence of copper. Normally copper ingots are used to produce copper or copper coins – how these ingots are prepared into coin blanks or copper metal artifacts of any kind based on the sophistication of the manufacturing process normally equates to what level of As we eventually see in both regal and CCC coinage.

Cast Coin – A coin made by casting liquid metal in a mold which contains the required designs. Cast coins were in fact produced in the period of the War of Independence (WOI) in Mexico. Cast coins are usually produced in a bronze type of alloy but also seen in silver issues with these WOI issues. Indeed, cast coins are seen as the lowest form of CCC with exceptions such as these highly sought after and prized WOI issues. Cast coins usually have undulations in the fields, air bubbles, vagueness and fuzziness of details in the coin's motifs. The coin's edge may also have file marks which is a finishing type operation to remove the protruding burrs on the edge from the casting mold operation. In this study we have seen cast coins from virtually pure copper with no lead, brass or zinc but this may be an exception more than a commonplace occurrence. Using SEM Microscopy in this study SEM photomicrographs were produced illustrating microstructures of cast coins being of a dendritic nebulae pattern seen with all three examples of George II Halfpence cast pieces in this study.

Class 1 Contemporary Circulating Counterfeit – A Gurney/Nichols/Lorenzo (GNL) classification from the Amazon Book - Counterfeit Eight Reales. It's a debased coin produced with reduced silver content, that was made to pass as current money or bullion in various countries without regard to date of production, with a silver assay below 800 fine. A refined definition of the CCC type used in the GNL publication in terms of its silver assay maximum value of 800 fine.

Contemporary Circulating Counterfeit (CCC) – A spurious coin made to circulate alongside originals in day-to-day commerce in the same value, regardless of the same value or design type. In this study the CCC's analyzed were Coins B & C which were Kleeberg types under the variety K.19A-L37. However further analysis showed Coin B to be a debased silver issue with copper, so it's no longer considered a Kleeberg regardless of it having regal or non-regal motifs. Debased silver hosts are prohibited in this CCC Kleeberg Family. The three cast English styled George II and two struck George III one being Irish and the other English in their design are all CCCs incorporated into this study to review their microstructure by SEM Microscopy and metal assays by EDS.

Glossary of Terms (continued)

Counterfeit Coin – A spurious coin used in commerce for the purpose of fraudulent gain. There are two types of counterfeits the desirable CCC's (Contemporary Circulating Counterfeits) such as Kleeberg Two Reales and Cast/Struck English/Irish George II/III Halfpence and Farthings which are both historic and numismatic worthy and the undesirable modern forgery issues or **counterfeit coins** like modern Chinese base metal fakes say of a U.S. Federal issue Morgan or Peace Dollar.

Debased Coin – Robert Gurney in his GNL book described as a term used by Riddell in reference to mint made coins of Spanish Republics that failed to meet the standard for silver content in terms of assay and which therefore are fraudulent. Debased coins are treated as genuine by collectors even though they are fraudulent in nature. In this study we determined Coin B was a debased silver issue with copper after reviewing both polished and unpolished SEM/EDS Map Sum Spectra's. Interestingly in CCC Eight Reales of debased silver are considered valuable and qualify for a Class 1 status whereas in the Kleeberg CCC Family they are omitted in having a variety number. In the latter case they are just too common and the Kleeberg's are preferred with hand cut dies and the rarer alloys such as copper, brass, bronze, German silver or brass/bronze mixture alloys. Each CCC Family has its own idiosyncrasies.

Dendritic Cast - A dendrite in metallurgy is a characteristic tree-like structure of crystals growing as the molten metal solidifies, the shape produced by faster growth along energetically favorable crystallographic directions. This dendritic growth has large consequences regarding material properties. In our study the dendritic casts were seen in the cast coinage of the George II English cast coinage seen in Phase III of this study.

False Positive - A false positive is when a scientist determines something is true when it is false (also called a type I error). A false positive is a "false alarm." A false negative is saying something is false when it is true (also called a type II error).

Image Transfer Process – One of several methods of directly transferring an impression of a three-dimensional object using any several media and methodologies to create a negative copy of the object suitable for casting or striking exact copies of the original.

Kleeberg Contemporary Circulating Counterfeits – The Carolus III, Carlous IV and Ferdinand VII Bust Types of the two reales denomination originally started by Dr. John Kleeberg and this author in 1998 followed by a C4 Colonial Newsletter update (Part II) and finally a Part III during the release of Forgotten Coins of the North American Colonies – 25th Anniversary Amazon book (21). Part I was the 1998 COAC-American Numismatic Society Publication), Part II was the Colonial Newsletter and Part III in Forgotten. The two coins for this analysis were originally given the same Kleeberg variety number K.19A-L37 as both obverse and reverse were from the same dies and hence the same counterfeit manufacturing operation. In the Facebook channel CCC – The Good Ones further Kleeberg varieties were added/recorded by this author for a forthcoming book of Kleeberg CCCs.

Map Sum Spectra - This map displays the element concentrations of the target elements, sometimes called a "quantitative map". In other words, the metal assay at a particular target point of a coin.

Glossary of Terms (continued)

Mercury Amalgamation Counterfeit – The process of mixing either silver or gold with mercury and spreading this mixture on the surface of the coin followed by annealing. In this study it was shown Coin C was a mercuric silvered surface CCC on a silver alloy debased with a bronze (Cu/Sn) mixture. It's the author's opinion that this is one the predominant silvering techniques in Kleeberg's and for that matter in most European CCCs of the 16th-19th Centuries. Silver plating and a more sophisticated form of silver plating called Sheffield plating is the other common-place counterfeiting technique to surface silver base alloys such as copper and pass these off as CCC issues. Silver plating is extremely rare in Kleeberg 2R's (only one reported/verified in the author's collection and in the (A-J) group mentioned in the Introduction but common in the 8R denomination for the GNL CCC8R types.

Microstructure – Microstructure is the very small-scale structure of a material, defined as the structure of a prepared surface of material as revealed by an optical microscope (i.e., SEM Microscopy) minimally above a 25× magnification level.

Mossman/Smith Empirical Formula – In their cast study Mossman/Smith report cast counterfeiters added several less expensive metals, notably lead, tin and sometimes zinc. Apparently, there was no standard alloy, whatever metal was available was added to the mix. Three examples from the Smith and Mossman study demonstrate the variety of alloys used; there was a 1737 George II halfpenny made from 91.3% copper, 5% lead and 3.7 tin; a 1740 George II halfpenny made from 66% copper, 25.9% zinc, 4.7% lead and 3.2% tin; and a 1775 George III halfpenny composed of 82.9% copper, 12% lead and 5.1% tin. In this study we confirmed cast nebulae microstructures with just a high copper alloy being detected however it can be argued more target spots may confirm the presence of lead which was added to help reduce the overall melting point of the casting liquid due to copper's high melting point and lead's much lower melting point. Roughly based on my research and reviewing Mossman/Smith the empirical formula can be considered as (Cu ~90%, Sn &/or Zn ~1-10% & Pb 1-10%). The author has examined dozens of cast specimens via XRF and most fall into the metal ranges of this so-called empirical formula.

Off-Metal – A generic expression used by numismatists to classify a CCC or modern forgery that it's not of a regal nature or legitimate issue. As an example, a regal legitimate two reales should be ~90% silver. It's an off-metal CCC if its silver content is not at this approximate level. Both Coins B & C in this study were determined as off-metal CCCs.

Point & ID Analyses – Utilizing a SEM Micrograph certain different shaded regions of black and white were selected for metal assay determination called spectrum areas. In this paper generally the level of 1000X magnification was chosen and different spectrum areas were circled (i.e., identified by the MSU analyst as target areas of analysis) and their metal assays in these regions were reported for each spectrum (i.e., target) area. The spectrum regions selected in a standard Point & ID Analysis normally number in the three to four range.

Glossary of Terms (continued)

SEM/EDX (EDS) - Scanning Electron Microscopy (SEM) with energy dispersive X-Ray spectrometry (SEM/EDS). Generally classified as an excellent analysis method for cultural heritage type material like coins. The chemical characterization of a coin facilitates the determination of the general provenance and age (i.e., CCC or Modern 20th / 21st century forgery). It also allows its technology of production (i.e., cast or struck), intended purpose and the overall authenticity (i.e., regal vs. non-regal). In this study with Michigan State University – Material Analysis Department a triple tier analysis method was utilized: Map Sum Spectrum/SEM Micrograph/Point & ID Spectrum Analyses.

Silver Surface Enrichment – A term which is now commonly used to describe the composition changes which have taken place during the life of a buried or unburied noble metal alloy. In fact, "surface depletion" is a better term, since it seems likely that it is the leaching out of the less chemically stable elements which causes the surface composition to change such as the case of copper leaching out of a high silver/low copper alloy. It should be remembered that silver surface enrichment can also occur with gold/copper alloys and like silver surface enrichment it can be intentional as in applying acid media to the surface or can result from natural corrosion processes over a period. In this study we confirmed elevated silver levels at the surface in the Phase IV analysis of the triple-tier SEM/EDS analysis of the regal (i.e., legitimate issued coin by a Mint) 1802 Lima Peru two reales coin.

Silver Wash – A chemical or mechanical process used to apply a thin silver coating to a counterfeit coin (CCC) using silver chloride dip or a silver-mercury amalgam paste. The term does not refer to an electro-galvanic or electrodeposited process of deposition of silver as it is much cruder than this method. Although not as common as gilding or gold wash using mercury it's also seen at times using the same principle as mercury which like silver has the same affinity for gold to be used in this application method and then generally followed by annealing to burn off the residual mercury which almost always is not successful and easily picked up by surficial XRF analysis done in a vacuum chamber or SEM/EDS which is always performed in a vacuum chamber.

Spectrum – In this study the spectrums were metal assays at a particular target area on a coin's surface. SEM Micrograph spectrum areas were selected for the different shades they exhibit in these Black & White photomicrographs. The different shaded regions indicate different metal or metal alloy regions within the SEM Micrograph. Any area selected by the Point & ID method can be characterized with its metal alloy make-up or the predominant metal in this area. The Map Sum Spectrum is also utilized and is the metal assay at a particular target area of the coin. Both are powerful tools in this three-tier SEM/EDS analysis method in metal alloy assay determinations.

Surface Contaminants – A group of metals found on a coin's unpolished surface originating from environmental air or soil exposure. Two common surface contaminants seen were sulfur (S) and chlorine (Cl) in this study. From previous studies by this author these two contaminants can be considered universally seen on all coin surfaces – it's just a question of what the wt.% will be that is recorded by the Material Analysis instrument such as XRF or SEM/EDS instrument.

Glossary of Terms (continued)

Target Area – In this study a random area of the coin's surface was selected for Map Sum Spectra analysis. In the spectrum areas within the Point & ID analysis particular areas of the SEM Micrograph is selected as a "target area "based on their different shades of Black & White intensity. So, a target area is a point of analysis which can be random (i.e., Map Sum Spectra) or non-random (i.e., Point & ID analysis spectrum area).

Triple Tier Analytical Method – With each target point at a coin's surface utilizing SEM/EDS analysis a Map Sum Spectra/SEM Micrograph/Point & ID Spectrum Areas are generated with the Map Sum Spectra and Point & ID yielding metal assay results of the coin's alloy and the SEM Micrographs yielding information if the coin is cast or die struck based on the coin's microstructure.

Twin (Grain) Line Microstructure – A microstructure seen in struck coins. Either a jigsaw like pattern or slip lines in the form of fine parallel or intersecting lines with slightly curved twin bands. Very different than the dendritic nebulae type microstructure of a cast coin. Sometimes it is also called a twin grain microstructure. Both terms are homogenous.

X-Ray Fluorescent Testing (XRF) – A non-destructive form of forensic scientific analysis (as is SEM/EDS) of the metallic elements contained in an object using "secondary" fluorescent emissions produced by bombardment with gamma or x-rays. Normally several target areas are recommended for unpolished surface coin areas as was the case with this study with "three" target areas being performed for both polished/unpolished areas of Coins B & C Kleeberg variety K.19A-L37.

References

1. Kleeberg, John. Circulating Counterfeits of the Americas – American Numismatic Society. Counterfeit 2 Reales of the Bust Type: Charles III, Charles IV, Ferdinand VII 1771-1821, A Survey and Die Study. November 7, 1998.
2. Gurney, Robert. Counterfeit Portrait Eight Reales. The Un-real Reales. Swamperbob Associates, Hope Mills, NC USA. September 1, 2014.
3. Larson, Charles M. Numismatic Forgery. Zyrus Press Irvine, California, USA. 2024.
4. Sigma Analyzer. The Sigma Metalytics Precious Metal Verifier PMV Basic Set with Case and Large and Small Wands. Sold by Sigma Metalytics. The Sigma Precious metal verifier is designed to test coins and bullion but generally not jewelry or scrap metals. For jewelry testing consider the Kee Gold Tester https://www.ebay.com/itm/122580426440 The Precious Metal Verifier is used to measure the bulk metal in a bullion bar or coin and ensure that the metal matches the electrical characteristics that would be expected of it. The Verifier can assess a sample in less than one second without affecting the coin or bullion in any way. No chemicals are used, and no physical damage is done to the coin or bullion being tested. Unlike in other testing methods, plating and surface features do not significantly impact the unit's ability to measure the underlying metal. Using electromagnetic waves that penetrate deeply into the coin or bar, plating and surface features are largely ignored, and the main body of metal assessed. The Verifier can see through plastic cases and bags, so numismatic coins do not need to be removed from protective holders.
5. Wikipedia. Various references used on the purpose and value of SEM/EDS analysis.
6. Darmstaedter, E., 1929, Subaerate Münzen und ihr Hestellung, Mitteilungen der Bayerischen Numismatischen Gesellschaft, 47, 27–38.
7. Campbell, W., 1933, Greek and Roman plated coins, Numismatics Notes and Monographs 57, American Numismatic Society, New York.
8. Cope, L. H., 1972, Surface-silvered ancient coins, in Methods of chemical and metallurgical investigation of ancient coinage, vol. 8 (eds. E. T. Hall and D. M. Metcalf), 261–78, Royal Numismatic Society, London.
9. La Niece, S., 1990, Silver plating on copper, bronze and brass, Antiquaries Journal, LXX, 102–14.
10. La Niece, S., 1993, Technology of silver-plated coin forgeries, in Metallurgy in numismatics III (eds. M. Archibald and M. R. Cowell), 227–39, Royal Numismatic Society Special Publication 24, London.
11. Zwicker, U., 1993, Katalog der Münzen in der Universitätsbibliothek Erlangen-Nürnberg, Band 2: Römische, byzan- tinische und Münzen der Völkerwanderungszeit aus den Sammlungen Will, Gerlach und Pick, Schriften der Universitätsbibliothek Erlangen-Nürnberg 23, Universitätsbibliothek Erlangen.
12. Anheuser, K., and Northover, J. P., 1994, Silver plating on roman and Celtic coins from Britain—a technical study, The British Numismatic Journal, 64, 22–32.

References (continued)

13. Beck, L., Bosonnet, S., Réveillon, S., Eliot, D., and Pilon, F., 2004, Silver surface enrichment of silver–copper alloys: a limitation for the analysis of ancient silver coins by surface technique, Nuclear Instruments and Methods, B226, 153-
14. Anheuser, K., and France, P., 2002, Silver plating technology of the 3rd century Roman coinage, Historical Metallurgy, 36(1), 17–23.
15. Vlachou, C., Janaway, R., and McDonnell, G., 2000, The metallurgical examination of the tetrarchic nummi, Proceedings of 2000 archaeometry conference, Mexico City, CD-ROM.
16. Gitler, H., and Ponting, M., 2003, The silver coinage of Septimus Severus and his family (193–211 ad): a study of the chemical composition of the Roman and Eastern issues, in Glaux: collona di studi e ricerchi di numismatica, 157, Edizioni Ennerre srl, 16, Milan.
17. Beck, L., Réveillon, S., Bosonnet, S., Eliot, D., and Pilon, F., 2003, Experimental evidence of direct silver surface enrichment on silver–copper alloys. Application to the analysis of ancient silver coins, in Proceedings of the Inter- national Conference on Archaeometallurgy in Europe, September 2003, vol. 2, 561–8, Associazione Italiana di Metallurgia, Milan.
18. Butcher, K., and Ponting, M., 2005, The Roman denarius under the Julio-Claudian emperors: mints, metallurgy and technology, Oxford Journal of Archaeology, 24(2), 163 –97.
19. Vlachou, C., J. G. McConnell and R. C. Janaway. 2002. Experimental Investigation of Silvering in late Roman Coinage. Material Research Society Symposium Proceedings. 712.
20. Caza, Shawn. The Life-Cycle of Late Roman Bronze Coins – A Tutorial. 2019.
21. Lorenzo, John. Forgotten Coins of the North American Colonies – 25th Anniversary Edition. Amazon Publication. 2014. See Appendix B of XRF results for various CCC Family types which were analyzed but primarily the Canadian Blacksmith Coppers in my private collection.
22. Scott, David A., Ancient Metals: Microstructure and Metallurgy: Volume 1. Copper and Copper Alloys. Printed by Cratespace.com and LuLu.com. 2012. See in this reference Figure 6.25 an example of a 60% silver/40% copper alloy in the cast state with very similar dendritic growth patterns to the three cast specimens in this study. These dendritic nebulae patterns are seen universally in most copper alloys in a cast state after reviewing three decades of cast microstructure micrographs of copper coin cast SEM images.

References (continued)

23. Charles W. Smith and Philip L. Mossman, "Cast Counterfeit Coppers in Pre-Federal America," *The Colonial Newsletter* 38, no. 1 (April 1998, serial no. 107) 1775-1803. Three examples from the Smith and Mossman study demonstrate the variety of alloys used; there was a 1737 George II halfpenny made from 91.3% copper, 5% lead and 3.7 tin; a 1740 George II halfpenny made from 66% copper, 25.9% zinc, 4.7% lead and 3.2% tin; and a 1775 George III halfpenny composed of 82.9% copper, 12% lead and 5.1% tin. In this paper we have confirmed that possibly lead was omitted along with tin and zinc and that a high copper alloy was cast molded. Unusual but the SEM microstructure micrographs, Map Sum Spectra and the coin in hand seems to confirm this non-economical way of producing casts since copper/lead has a much “lower” melting point than high copper and therefore less fuel was required. Perhaps in this CCC manufacturing operation fuel costs were not a concern.
24. Standard Catalog of World Coins 1801-1900. 7th Edition. Krausse Publications, Iola, Wisconsin. 2012. The so-called Krausse/Michler numbering system which are represented by a KM numbering system under the individual countries such as this example under KM#95 under the two reales denomination.
25. We see high levels of Arsenic in the spectrum assays only when we see high copper levels. In the very informative reference “Scientific Investigation of Copies, Fakes and Forgeries” Paperback Version; 2020; British Museum Publication by Paul Craddock on page 387 Craddock writes of ancient silver production which also correlates to Gurney and Lorenzo’s investigation of counterfeit 8 Reales containing lead and trace gold when high silver was found. Craddock states “It is also difficult to remove all traces of the lead (silver production and its compositions), which is therefore normally present in trace amounts in early silver. Note that very early silver, emerging from native silver or very rich silver ores that could be smelted without recourse to lead to absorb the silver, may contain very little lead. For example, silver of the Bronze Age Argaaric cultures from south-east Spain contain little or no detectable lead at the 0.01% analytical detection limit. Similarly, the presence of traces of volatile metals such as arsenic and zinc indicates that the metal had not been cuppeled, as these metals would have otherwise been completely removed. However, there is always the possibility that the silver may have been alloyed with copper containing these two metals. This seems to be the occurrence here whereupon some Map Sum Spectrums and Point & ID spectrums showing high copper do then reveal arsenic in varying amounts strongly suggesting the presence of arsenic is from this metal source - copper.

References (continued)

Craddock on page 141 concerning arsenic as a trace element elaborates further on arsenic – A substantial quantity of arsenic sometimes amounting to several percent is often found in very early copper artefacts. Similar compositions occur in Medieval and Post-Medieval European metalwork. Right up to the end of the 19th Century, European copper could be surprisingly impure, as evidenced by the composition of copper manillas, made in their millions in Birmingham for the West African market in the 19th Century and first half of the 20th Century. Arsenic is also found in some of the more recent *irogane* patinated alloys. Note that arsenic tends to become concentrated at the surface of copper alloys, and that arsenic salts were common components of many 19th – 20th Century "bronzing" patination treatments. Thus, a high arsenic content in the surface of a copper alloy does not necessarily mean that the metal has the same arsenic content." Author – This is the case here where high arsenic levels were seen at the surface but after polishing the test coins (B & C) in particular this surface contaminant coming from copper seems to disappear in accordance with the findings of Craddock.

26. The two most common contaminants forming on a coin's surface are chlorine (Cl) and sulfur (S). There are multiple references for this occurrence. As an example in the reference "Scientific Investigation of Copies, Fakes and Forgeries" Paperback Version; 2020; British Museum Publication by Paul Craddock on page 388 Craddock writes about silver: The most common products of silver corrosion are silver chloride (horn silver), or silver sulphide (silver glance), depending on the burial environment. The silver chloride forms a waxy deposit on the surface, the sulphide forming a dense black layer. Silver has frequently been alloyed with copper (author: as with Coins B & C) and the copper is more electronegative it will corrode preferentially, and thus a silver antiquity, with say no more than 10% copper, may have a firmly adhering green patina formed almost exclusively of copper salts. Even when silver chloride does form as well, its purple hue can be mistaken for cuprite. Author: The presence of chlorine (Cl), sulfur (S) and silicon (Si) are all forming oxides with both silver and copper in these coin examples. We see their disappearance from the assays when we view the Map Sum Spectrums of the polished areas of Coins B & C in the Phase II study clearing showing these were surface oxide contaminants. This author has also confirmed a coin need not be buried to pick up these two common contaminants from either air exposure and/or long periods of handling.

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methodology all-encompassing a single target point on each coin's surface. From this analytical approach, the paper evolved with two contemporary circulating counterfeits with regal motifs being analyzed (Coins B & C). We then analyzed five English/Irish George II/III Halfpence to differentiate between their cast/struck microstructure surfaces and metal assays. Finally, it was necessary to analyze a regal (i.e.., legitimate 90% silver) 1802 Lima Peru two reales as a standard 90% silver issue to further compare to coins B & C both confirmed as contemporary circulating counterfeits of the period.